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SOME SIMPLE CONSIDERATIONS OF COMBUSTION AND GAS DYNAMICS IN LIQUID PROPELLANT ROCKET MOTORS

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SUMMARY

Rocket motors using liquid chemical bipropellants are discussed with reference to the problem of the injection, mixing and combustion of the propellants, transfer and dissipation of waste heat, interior ballistics of the motor and stability of burning. Some comments are made on the design and performance estimation of typical small rocket motors.

Introduction

I wish to discuss, in a simple way, some of the things which are believed to go on in rocket motors using liquid bipropellants. I say believed, because the rocket motor is a very difficult piece of equipment to investigate when performing in the manner intended, though in repose it is probably the most deceptively simple prime mover that exists today.

As a broad indication of the difficulties we are up against, a typical small bipropellant motor may experience within it a pressure of some 300 lb./in.^{2} exerted by gas at a burning temperature of up to 3,000°K. As you know, mild steel melts at about 1,550°K, and the only metal which would stand up to the burning temperature is Wolfram or Tungsten, which melt at 3,675°K and are used in electric lamps running at 2,850°K, though expensive and very difficult to work. In addition to the high temperature, certain propellants in common use are violently corrosive, and this combination of difficulties has made it impossible to investigate the processes occurring in the rocket motor with the same directness or comprehensiveness as in purely aerodynamic phenomena.

Conditions prevailing in Liquid-Propellant Rocket Motors

After having made my apology for knowing very little about the subject, I will attempt to contradict myself and show you as clearly as I can what is thought to go on in a rocket motor. Fig. 1 (overleaf) shows a rocket motor which, if not representative of any particular school of thought, shows some of the salient points we will have to consider.

This particular motor is regeneratively cooled by the oxidant, which passes round a jacket covering the motor shell proper and is guided by spacing wires in the gap so formed. I have shown an injector which forms the front end of the motor and which has two rings of jets concentric with the motor axis, and the jets are so arranged that streams of the propellants emerge from them and impinge together a little way into the combustion space. The resulting stream of mixed propellants has a direction which is usually approximately axial.

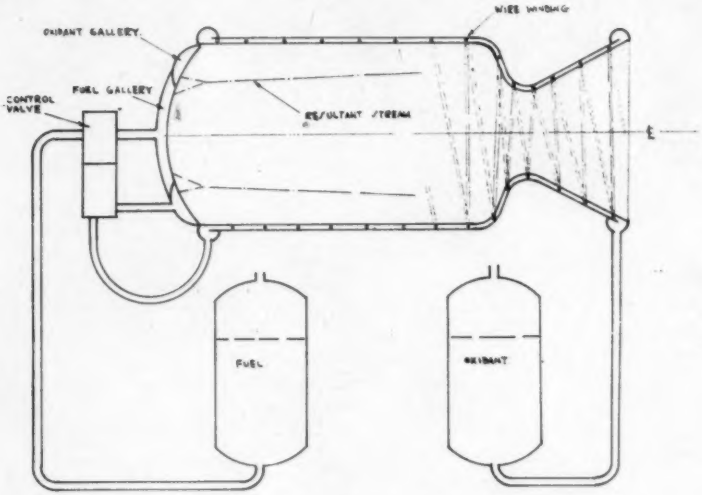


FIG. 1. Arrangement of a typical bi-propellant rocket motor.

In Fig. 2 we can see the changes in mean pressure, temperature and velocity which occur in the motor, subject to a lot of conditions which I will discuss later. In the body of the motor conditions are constant, although we might justify the presence of a finite length of chamber and indicate the combustion going to completion by drawing the line for temperature dashed as shown: the maximum value should be that attained by a fully burnt mixture. As soon as we reach the beginning of the nozzle things begin to change; the flow is accelerated through the constriction, with consequent drops in static temperature and pressure, until it reaches the region of the throat, near which the gas achieves its local velocity of sound. This region is important because the cross-sectional area of the nozzle here controls the propellant discharge rate for a given burning pressure, and, for a given medium, it is easy to show that for unit area of uniform flow at sonic velocity the quantity $\dot{M}\,T^{\frac{1}{2}}/P$, (where $\dot{M}$ = mass flow rate and P and T = local static pressure and temperature) is approximately constant for any given gas and exactly constant for a particular perfect gas, and P and T are dependent on the combustion pressure and

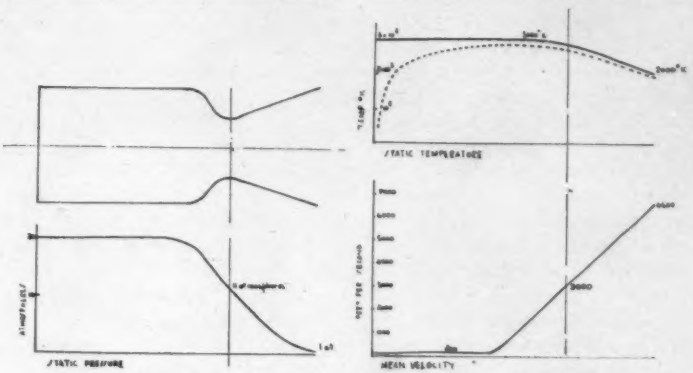


FIG. 2. Average conditions inside a typical motor.

temperature. T does not vary much with pressure over a small range, and so if we know approximately the changes in P and T between chamber and throat we can choose the throat size for a given motor. Once past the throat, the gas continues to expand and becomes generally supersonic in velocity, with reductions in static pressure and temperature until the pressure is usually slightly less than that of the atmosphere near the ground. In the case of a space rocket we want to expand as far as possible, since the ambient pressure is zero, and so we need a large nozzle. If we expand through a pressure ratio of 10^6, the nozzle throat exit area ratio is about 2×10^4, so all nozzles actually made will be much smaller, and many nozzles for missile motors have an area ratio between 4 and 5.

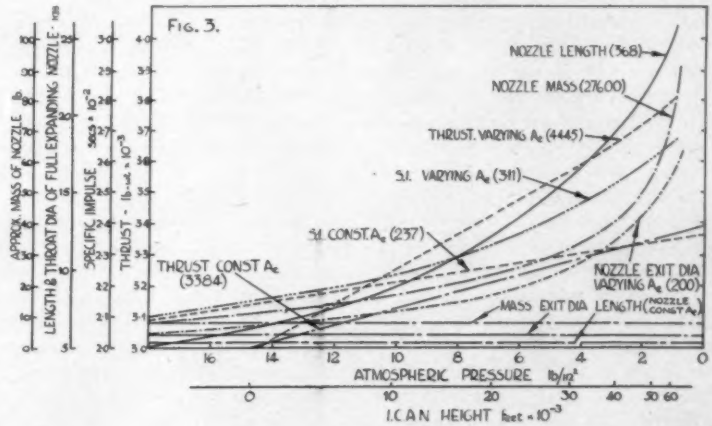


FIG. 3.
NOZZLE LENGTH (368)
NOZZLE MASS (2700)
THRUST. VARYING A_e (4445)
SI. VARYING A_e (311)
SI. CONST. A_e (237)
THRUST CONST A_e (3384)
NOZZLE EXIT DIA VARYING A_e (200)
MASS EXIT DIA LENGTH (NOZZLE CONST A_e)
APPROX. MASS OF NOZZLE lb
LENGTH & THROAT DIA OF FULL EXPANDING NOZZLE - ins
SPECIFIC IMPULSE secs × 10^{-2}
THRUST - lb-wt × 10^{-3}
ATMOSPHERIC PRESSURE lb/in²
I.C.A.N. HEIGHT feet × 10^{-3}

FIG. 3.

We can illustrate this more fully by means of Fig. 3, where I have considered two rocket motors, both giving 3,000 lb. wt. thrust at 300 lb./in.^{2} chamber pressure, but having different nozzles. One of them has a constant exit area, designed to give correct expansion at sea level, and the other grows with altitude to a size which enables it to expand to the local ambient pressure at any height. The graph covers altitudes up to 60,000 ft., where the air pressure is about 1 lb. per in.^{2} As the altitude increases (or the back pressure diminishes) both motors increase their thrust and specific impulse, since the burning rate must remain constant, but the motor with varying exit area is much superior to the other from this aspect. In particular the thrust and specific impulse increase almost uniformly with height for the variable exit motor, which is not at all the case with the other motor. This improved performance, however, is not attained without penalties, and we can see what these are from the curves of size and mass. At about 60,000 ft. the required nozzle is about 16 in. in diameter at the end and 24 in. long, and weighs 85 lb. or 70 lb. more than the equivalent motor designed for sea level expansion which gives the same thrust at altitude. If we want to cruise for say 30 secs. at a given altitude, we can show that the extra mass of propellant and tank for the less efficient motor is almost exactly balanced by the mass of the big nozzle up to 60,000 ft., not to mention the difficulties introduced by the additional length of the rocket.

No doubt many of you may think that 60,000 ft. is a paltry altitude, but I will show what happens if we design our big nozzle to operate at 43 miles up, where the air pressure has fallen to about 0·002 lb./in.^{2}; here we are nearly in empty space but not far out in the earth's gravitational field. The values of the variables for this height have been given in Fig. 3 in brackets, and it is interesting to see that the thrust of our motor with a growing nozzle is now 4,445 lb. wt., and the fixed-nozzle motor gives 3,384 lb. wt. which is a nice increase in thrust. The growing nozzle, however, is now quite big: it is 200 in. in diameter at the end, 30 ft. long, and weighs over 12 tons, which should be compared with the complete fixed-nozzle motor which for the same thrust weighs 55 lb. Even if we consider our flight of 30 secs. at constant altitude and thrust, the use of a fixed-area motor saves 27,400 lb. in mass.

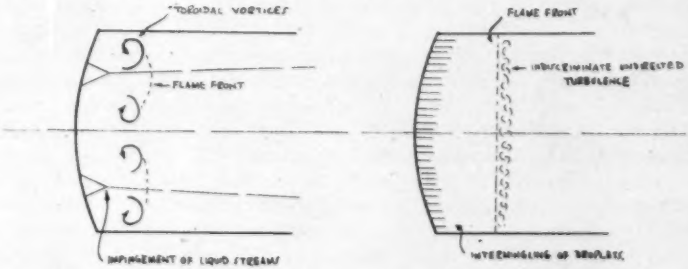
The basis of these calculations is rather hypothetical, but we can show that the propellant chosen simulates a well-known propellant pair quite closely, at least near sea level; the requirement of 30 secs. flight at constant altitude is somewhat arbitrary and neglects the propellant needed to raise the rocket to the altitude, but it is put in to give a working example.

I think a comment should be made here as to why we need to tolerate such high temperatures in rocket motors. Fairly obviously, we could reduce the maximum combustion temperature to any desired amount by mixing with one of the propellants an inert material such as water or nitrogen, or by running fuel rich, so that, for example, we could have a motor operating with a gas temperature of say 1,300°K. The answer is quite simple: if the motor is to be any good, it must burn its propellants as usefully as possible and this means achieving the highest possible exhaust velocity. To do this we must convert as much heat as possible into the mechanical kinetic energy of the exhaust, and this means a large heat drop through the nozzle, which can only

be got with a high initial temperature since only the temperature ratio is a function of the pressure ratio. Even if an infinite pressure ratio could be used we should get, in the example above, only a temperature drop of 1,300°C: with a combustion temperature of 3,000°K we should need only a pressure ratio of about 30 to achieve the same heat drop and consequently the same specific impulse, neglecting changes in molecular weight.

The Combustion Process

Having described very generally and briefly the conditions which prevail in a rocket motor, I must now turn to the mechanisms which produce such conditions, and it seems logical to start with the combustion process. Fig. 4 illustrates diagrammatically two forms of injection system, and we will consider first the mixing of the propellants in the left hand one, which is the same as that shown in Fig. 1. The streams of propellant emerge from the jets at velocities given by the pressure drop across the injector which are high enough to ensure fairly thorough mixing in the liquid state and prevent rough running, and the mixed stream passes into the region downstream which already contains hot gas from burning propellants, and is ignited on its surface. The initial release of heat causes vaporization and a more rapid reaction of the propellants which burn generally to gaseous products at a very high stagnation temperature with intense turbulence usually in the direction shown by the curly lines in Fig. 4. This combustion process should be completed as nearly



Impinging jet concentric injector

Non-impinging repetitive pattern injector (showerhead).

FIG. 4.

as possible within the combustion chamber proper, as delayed burning during expansion in the nozzle inevitably causes a decrease in the available heat drop and so a reduction in performance. Therefore, in order to obtain a small motor we must make the combustion take place as quickly and completely as possible, although it must be smooth. These requirements are difficult to achieve, and fairly naturally in the present state of politics details of the successful methods are kept secret, but I will give you a few ideas on desirable procedures. In order to minimize the time taken to get the propellants into the vapour state where burning takes place, it seems logical to use injectors which produce either thin sheets, fine streams, or conical sprays as in normal

gas turbine practice, but unless we pre-mix the propellants the last of these makes the complete mingling of the fuel and oxidant in the chamber almost impossible to achieve. If we have many small jets in which thin streams of the propellants mingle by gentle diffusion, as shown on the right hand side of Fig. 4, the problem becomes simpler, and we can achieve complete intimacy in a very small space of time. This is highly satisfactory, but there are engineering difficulties in drilling many small holes, and, as always, a compromise has to be used in which, for example, we have a reasonable number of fairly small jets which give impinging streams. The arrangement of impinging sheets of propellants, although promising in concept, is rather difficult to achieve.

Of course, if we have large jets which give streams of propellant which mix thoroughly and then pass quickly into a region of very high temperature, the reaction may take place completely and rapidly and almost in the liquid phase, but there is a tendency towards rough running which is not apparent with many small streams flowing into a relatively gentle temperature gradient in which the system is tending towards the vapour phase.

Before leaving the combustion process, I should mention the vibrations which occur under some conditions of burning. Usually these vibrations are of one or two types, with characteristically high and low frequency, but both have great intensity. This subject is one on which I should hate to be quoted, but the state of things seems to be rather as follows. Taking low frequency oscillations first, there may be three basic causes: the first is resonance in the propellant feed lines, which give periodic pulsations to the flow into the motor excited by the normal random vibration spectrum of burning, the second is an alteration of the discharge coefficients of the propellant jets by a change in the back pressure, and the third is vibration of a plane flame front when the velocity of the propellants through it is so high as to be near the maximum burning rate. This last cause seems important with shower head injectors, but concentric impinging jet injectors, with their recirculation of hot gas, do not suffer so badly. These causes give combustion which may pulse at about 30 c/s., and may shake the motor and test bed to pieces in a very short time, and a cure may be effected sometimes by increasing the injector pressure drop or the combustion pressure.

The high frequency vibrations may be caused by organpipe resonance in the combusion chamber itself, excited by the general combustion noise. Not much can be done about curing this except by a redesign of possibly considerable magnitude. Vibration in rocket motors is, in fact, a quite poorly understood phenomenon altogether.

Design and Performance

We have now reached the stage where we have burnt as much of our propellants as we can to equilibrium in the combustion chamber, and so there is a mass of gas flowing comparatively uniformly along the chamber; the intense small-scale turbulence of burning will ensure that, except close to the injector face and very near the motor walls, the mean velocity profile across the chamber

is almost straight. We need to convert the energy released by the combustion into a form which will produce a useful thrust. The way we do this in a chemical rocket is to expand the burnt gas so that its pressure becomes nearly that of the outside atmosphere, the corresponding heat drop being used to accelerate the gas, and as indicated previously, a simple convergent-divergent nozzle is used. In order to determine the performance of such a nozzle, we have two paths open. In one, we can assume that the expanding gas has a constant chosen value of C_p/C_v or γ between the temperatures involved, which is a rather approximate method, and which was used in some data already discussed, and in the other we employ an entropy-enthalpy chart for the perfect combustion of the propellant combination used, which makes allowance for the changes in specific heat with temperature and in gas composition due to re-association, and enables very accurate estimates to be made of the throat size required and the attainable specific impulse with an expansion to a given pressure. Unfortunately both these methods apply to an idealized state and to one dimensional flow, and the gases we encounter are neither in equilibrium nor are they completely burnt, nor is the flow one dimensional. Theoretically it may be possible to construct an entropy-enthalpy chart for a partly burnt mixture, but as the products of partial combustion vary with the equipment in which the reaction takes place, there is not much hope of the job being worth while.

It is regrettable but true that at the moment the most accurate method of design and performance prediction is that of tradition and comparison. Simple scaling can, however, be indulged in, and is quite good for a limited range of chamber pressures and thrusts, for a given propellant combination.

I do not propose to quote any data which give an indication of the quantitative effect of neglecting dissociation and changes in specific heat, but qualitatively we find that the actual ideal combustion temperature is depressed when compared with that computed on simple combustion theory, to the advantage of the designer since the heat released to kinetic energy on expansion is not effected as much as the motor wall temperature would be.

The usual method of completing the design of the nozzle, once the throat and exit areas have been chosen, is to take a fairly rapidly-convergent entrance, smooth rounding at the throat, and a conical divergent portion which has not so large a taper that the flow detaches itself from the wall. Obviously there is no great advantage in making the nozzle angle so small that the length of the nozzle becomes very large, as then the mass of the motor and friction losses will rise. The stream in the divergent portion is supersonic, as I have indicated, and it may be asked why a proper supersonic nozzle (designed by the method of characteristics, for example) is not used. The answers are several: the shaping may require special machine tools, the computation for a gas with changing specific heats and constitution would be extremely difficult and we do not know the constituents or the specific heats, the back pressure on the nozzle is always varying in flight in an atmosphere, and probably even a very refined rocket test bed would not notice the difference anyway: so we use one dimensional theory and plain conical nozzles, and neglect the fact that the gas does not reach sonic velocity exactly in the throat plane.

Heat Protection of Motors

I have indicated before that the combustion temperature commonly experienced is about 3,000°K and one of the aims of a rocket designer is to make a motor that does not melt within two seconds after ignition—which leads us to discuss methods of cooling the motor and the way heat is transferred from the inside to the outside of the motor. In my view, there are three schools of thought on motor design from this aspect: one advocates liquid (regenerative) cooling of an all-metal motor such as was shown in Fig. 1, another chooses a metal outer shell with a refractory liner, and a third favours either sweat or film cooling, though the most success seems to come from combinations of the first or second method with the third.

An excessively simplified theory of heat transfer in rocket motors has been put forward in which the various inner sections of the motor are treated as being occupied by what hydraulic engineers call "fully developed pipe flow," and which is characterized by turbulent flow with a velocity profile given fairly closely by a seventh-power of the distance from the motor wall, although there is a laminar sub-layer close to the wall, and by the mean flow being substantially parallel to the walls, which themselves should be parallel. This concept lends itself to the classical treatment given in most text books on engineering thermodynamics, in which the gas film conductance becomes

$$h_g = 0{\cdot}021\ K/d \times R^{0{\cdot}8}$$

where K is the gas conductivity at its mean temperature and density, d is the diameter of the channel (assumed circular) and R is the Reynolds' number of the mean flow in the channel, based on the channel diameter.

The troubles here are that K can only be deduced if we know the composition and temperature of the gas near the wall, which can only be determined experimentally by techniques at least as difficult to develop as one for measuring the heat transfer itself. Using the theoretical values of the gas composition may introduce errors of considerable magnitude, while the mean gas temperature should be one of the results of our calculation, and if there is one thing we are reasonably sure of, it is that the velocity profile in the motor is *not* that of fully developed pipe flow. Also, this method ignores radiative heating, which may be considerable inside the motor body. In addition, the flow in the nozzle accelerates to a supersonic velocity, and the amount of data available for heat transfer calculations even for air at moderate temperatures and supersonic velocities is quite scanty.

Even if we develop methods which take a rather more realistic approach to the nature of the gas flow in the motor, by the application of boundary layer theory, the assumptions which have to be made are usually so sweeping that the answers are usually wrong, and if we adjust theory and practice by the introduction of suitable empirical factors, there is no guarantee that a given formula will be applicable to more than one particular motor. In consequence, we are driven to reliance on fairly crude experimental methods, such as measuring the temperature rise of a known flow rate of coolant through a rocket motor jacket, or by burying thermocouples in a solid copper nozzle and plotting the movement of isotherms during a short period of combustion.

Methods such as these have three basic defects: (1) usually, once a motor can be made to last in a comparatively undamaged state for say three seconds, it will have a useful life of maybe ten times as long, so that we cannot get information which will tell us how bad a design is, but only confirm that it is fairly good; (2) there is difficulty in determining at any time the heat transfer rate and the local wall temperature in any particular small region; and (3) results from a series of tests on one particular motor design almost always cannot be applied to motors of more than slightly different design. Consequently the usual way of developing a combustion chamber is by rule-of-thumb methods.

I think it will be apparent that the way in which the propellants are injected will have a most marked effect on the heating of the motor, but I will give two examples. Referring to the right hand side of Fig. 4, if we have an injector which introduces propellants fairly uniformly over the cross section of the combustion chamber, combustion will be initiated near a given transverse plane, and the process will continue smoothly along the chamber at a low mean velocity, which means low heat transfer to the walls. In the other case, if we have an injector which introduces the propellants in, say, a ring concentric with the chamber axis, the burning will be initiated somewhere in an annular region, and this will give rise to two attendant toroidal vortices, one inside and one outside the ring of injected propellants, which may have high angular velocities and which transport burning propellants into immediate contact with the chamber walls which they scour and burn.

Even the first of these injection systems will give unduly hot chamber walls, whether the walls be of regeneratively cooled metal or refractory material, and it is usually necessary to provide some internal cooling. This can be done with either of the two propellants, although it is desirable to choose the one which does not attack the chamber wall or which will persist longer than the other as a liquid film, and it can take the form of either a surface film on an impervious wall, produced by small jets playing on the wall, or a diffused film oozing through a porous wall. The film really serves two purposes: it protects the wall from chemical attack and insulates it by absorption of latent heat from the burning gases. However, even with quite copious film cooling, there is a high rate of heat transfer to the motor walls, usually sufficient to heat uncooled steel to its melting point, and we must now consider regeneratively cooled and refractory lined motors.

The first of these relies on the inner wall of the motor being thin enough, and the coolant flow rate high enough, to prevent the surface of the inner wall, in contact with the hot gas, from reaching a temperature where it will lose a large amount of its mechanical strength. If we have a large diameter chamber, there may be a difficulty with the thick inner wall needed to resist the collapsing load due to the jacket pressure, but if we adopt relatively long thin motors the cooling can be done satisfactorily without needing excessively high coolant velocities with their attendant high pressure losses. The heat transfer from the metal wall to the coolant can be dealt with in some cases by classical methods, but in regions where the transfer is very high, as for example near the throat of the nozzle, the phenomenon of so-called nucleate boiling

may occur, and attempts to calculate the inner skin temperature by measuring local heat transfer rates may be inaccurate just where they would be of most value. Once again, experience is the only guide at present, but a fairly optimistic view is that when using film cooled motors the walls will not overheat if there is no tendency for the coolant to form local pockets of vapour. One rather interesting point with regeneratively cooled motors is that, below a certain thrust level, the cooling problem becomes very difficult as the reduction in chamber diameter increases the heat flow to the walls, but the amount of coolant available is reduced, and so the coolant channels have to be so narrow as to produce a considerable engineering problem in getting uniform flow rates with reasonable manufacturing tolerances.

The refractory lined motor has no cooling other than the internal film cooling and the natural loss by convection and radiation from its outer surface. It relies for its survival on the high softening temperature of the refractory material in contact with the hot gas, and the low heat transfer through the refractory and its backing material, which prevents the metal shell getting too hot in the duration of firing. Commonly used refractories are various mixes containing silicon carbide, and they are backed with plaster of paris.

We can now see a major difference between the two types of motor arrangement, in operation as well as in construction. The regeneratively cooled motor, provided it is not subjected to erosion or corrosion by the burning propellants, gets into a steady state of heat flow almost immediately it is ignited, and in this state can continue to operate for as long as there are propellants to feed it. The refractory lined motor, however, has a low heat flow and low heat dissipation, and is getting hotter and hotter all the time of firing, so that there is a definite maximum endurance for any one firing, limited by the temperatures reached by either the inner surface of the refractory or the metal shell. These differences in operation, together with the relative simplicity of the refractory lined motor, seem to point in turn to differences of application. The regeneratively cooled motor is essential where a long duration is required without the necessity for cheapness of construction, as in the power plant of a piloted aircraft, and it seems logical that a simple cheap refractory lined motor should be used for a one-shot expendable application.

Conclusion

In my view, the liquid propellant rocket motor of medium size stands, as regards design, where the gas turbine combustion chamber stood in 1942: then, combustion efficiency was about 80 per cent. and chamber endurance was measured in minutes. Today, combustion efficiency is about 99 per cent., and overhaul periods are reaching the 500-hour level, all with simpler, lighter and cheaper design and construction. This has been brought about largely by increased knowledge of the combustion process and the gas flow, and it is not too much to hope that the chemical bipropellant rocket motor will make similar strides once the stage of *ad hoc* experimentation is passed, though it seems unlikely that the atmosphere of calm and unhurried research needed to perform some very elegant experimental work and its analysis will descend upon us while the rocket is merely an urgent military requirement.

"BRAINS TRUST"

As it was impossible to obtain security clearance for Mr. Humphries' lecture "The Guidance and Control of Missiles," scheduled for December 13, 1952, an impromptu "Brains Trust" was organized instead. The panel of hastily conscripted Brains comprised: A. V. Cleaver, K. W. Gatland, R. A. Smith and G. V. E. Thompson, with Mr. Clarke as Chairman. The proceedings were recorded, and as it is thought that some of the questions and answers may be of general interest, a selection is given below. The programme was generally enjoyed, and may well be made a permanent feature of future sessions.

Question: Can the Trust give a simple explanation of the so-called "Time Paradox"?

A. V. CLEAVER: I don't pretend to understand the time paradox myself, but there is one observation I would like to make. This paradox arises in space travel at speeds approaching that of light, and follows from the Theory of Relativity. As this Theory is now quite well established, the best opinion in physics does believe that these things will happen. They seem to be against all common sense, but why should we expect common sense principles to be obeyed over vast astronomical distances and at speeds right outside the range of everyday experience? It is surely human conceit to imagine that under such totally different conditions things should go on in just the way we are used to!

A. C. CLARKE: Dr. Shepherd has dealt with this point in his paper "Interstellar Flight" (*J.B.I.S.*, **11**, 149–67, July, 1952) and in later correspondence (*J.B.I.S.*, **11**, 297–99, November, 1952). The fact that it is theoretically possible to travel at nearly the speed of light and then return to one's point of origin thousands of years later, having aged only a few years oneself, is just one of those things that must be accepted unless you can follow the mathematics of the Theory of Relativity! (And, incidentally, the General, not the Special, Theory is needed for the full explanation.) The effect has been experimentally demonstrated in cosmic ray studies, so it's not merely something that the mathematicians have worked out on paper! Personally, I don't see why it should be a bigger paradox than the fact, arising from the same theory, that matter can be converted into energy. And *that* is something that few people will deny to-day!

Question: What are the military advantages of a space-station?

K. W. GATLAND: More nonsense has been written about the military advantages of artificial satellites than anything else in astronautics. Certainly a satellite up above the Earth would be able to spy upon countries testing weapons and preparing for military exercises, but when one thinks of using a satellite as a bomb carrier, that is an entirely different proposition. It's far more economical to shoot a rocket from the surface of the Earth against an objective on the other side than to project it into an orbit, and then bring it down again some time later. Moreover, a satellite would be a very vulnerable object because its position could be calculated at any time with absolute precision.

A. V. CLEAVER: I don't think it would be true to say that the satellite would have *no* military uses. It might have advantages as a reconnaissance post out in space, and very likely a use as a radio relay for relaying short wave signals used for the guidance of purely conventional missiles flying in the atmosphere beneath. I am sceptical about its uses as a bomb carrier. I was amused to see that in the original series of articles about the space-station in *Collier's* magazine, von Braun didn't seem to feel it necessary to answer this question, but when the criticism was made from many quarters afterwards, he did devote a few paragraphs to it in the book version, *Across the Space Frontier*. He replied by saying that the satellite would carry defensive missiles to fire against the offensive ones coming up from Earth. I think it would have to carry rather a lot, and it certainly couldn't do much in the way of evasive action! I am sure it would not be the sweeping advance towards military security which von Braun has often claimed.

Question: How far have the Americans got in the development of the artificial satellite?

A. V. CLEAVER: As I don't know, I'm quite sure that M.I.5 can't slap me down for answering this! My guess, for what it is worth, is that they have certainly got project study groups doing theoretical studies of satellite vehicles of various sizes, but I don't think that anything beyond the theoretical stage has yet been done. At the same time, it cannot be over-emphasized that all work on rocket vehicles contributes in some small measure to space-flight, so that in that sense quite a lot is being done at present. The first thing that will happen, in my opinion, is the building of quite a small satellite vehicle purely for research purposes. It would be something that would go up and orbit the Earth for a few weeks carrying automatic instruments and telemetering information back as an extension of existing work on cosmic rays and other high-altitude phenomena.

Question: In a recent "Time" article, it was stated that rocket development was a prime cause of Germany losing the War, as it drained off so many scientists. Has the Brains Trust any comments on this?

K. W. GATLAND: von Braun admits, in a book I am editing, that his main interest in rockets was for space-flight and that he tried to get the authorities to take them up in order to obtain more money. Another interesting point he makes is this. It is often thought that the V.2 was conceived as a weapon of destruction against cities. In point of fact it was intended to be an Army ground to ground missile, but at the instigation of Himmler it was turned against London when it was found to be successful.

Question: In the same "Time" article, it was stated that a "closed biological system" of the type envisaged when we consider spaceships making journeys lasting hundreds of years would involve cannibalism. Surely this is rather bad publicity!

G. V. E. THOMPSON: Of course, this question only refers to interstellar travel, not interplanetary travel. We have a closed cycle here on Earth, and we already live on our own dead bodies, though these have passed through several intermediate stages. It has been said that when we drink a glass of water, it contains some of the molecules from the glass of hemlock that Socrates drank!

A. C. CLARKE: I think that this particular comment was a piece of *Time*-like impishness in an excellent article! The answer seems to be that if the "closed biological system" is large enough, we aren't cannibals!

Question: Why can a rocket travel faster than its exhaust?

A. V. CLEAVER: A rocket represents a certain mass, and as long as the thrust is operating, it will continue to accelerate. As long as matter continues to be expelled at a constant rate in the exhaust, so the thrust will be maintained at a steady value. This thrust will act on the continually decreasing mass of the rocket, so as long as any propellant remains the rocket will go on gaining speed.

Question: Are there any further hazards that astronauts may have to face besides those generally known? What about the radiations from the so-called "dark-stars" recently discovered?

A. C. CLARKE: I presume the speaker is referring to "radio-stars." That is a non-committal name given to the point sources of intense radio emission discovered since the War: no one knows if they really *are* stars of some peculiar type. In any case, the actual energy of the waves, as compared with that of cosmic and other radiations, is minute and of no biological importance. It cannot be compared with the radio fields in which we now spend all our lives!

Question: In one of his books, the Chairman referred to the use of radio grids for the navigation of spaceships. What was meant by that?

A. C. CLARKE: I was thinking of short-range navigation near a planet: I cannot see any use for radio aids in interplanetary space. What I had in mind was something like GEE or the Decca System. There we have a number of transmitters (usually one master and at least two slaves) sending out radio waves in synchronism. A receiver in the combined fields will receive a certain pattern of waves, according to its position. This may be found, to a very high degree of accuracy, from special maps. A three-dimensional extension of the same system might be of use in space travel.

"MAN ON THE MOON"

Collier's magazine, following up its earlier symposium on space-flight, devoted much of its issues of October 18 and 25, 1952, to a series of beautifully illustrated articles on the first expedition to the Moon. The members of the panel were Willy Ley, Dr. Fred Whipple and Dr. Wernher von Braun. The series was edited by Cornelius Ryan, and illustrated by Chesley Bonestell, Rolf Klep and Fred Freeman. Just as the previous symposium appeared later in the book *Across the Space Frontier*, so we understand that this material will be published in volume form around the end of 1953.

The first article, "The Journey," is by von Braun, and describes an expedition of fifty scientists in three ships—two passenger ships, and one supply ship which would be left on the Moon. The vessels would be built and fuelled in an orbit 1,075 miles up—an unnecessarily great altitude, one would think, for efficiency. The ships are of the non-streamlined, open-construction type already described in *Across the Space Frontier*, with additional landing legs and many more motors. Nitric acid and hydrazine are used as propellants. The vehicles are 160 feet long, 110 feet wide and weigh 4,370 tons.

A magnificent double-page spread by Chesley Bonestell depicts the building of the ships in the space-station orbit, and fine cut-away paintings by Rolf Klep show their construction.

A short article, "Inside the Moon Ship," by Willy Ley, is illustrated by Fred Freeman and explains what life will be like in one of the passenger ships. A careful scrutiny of the painting shows Willy Ley having difficulty with a hatch, and Dr. von Braun relaxing in a contour couch!

It is considered that the most suitable place to make a landing is the *Sinus Roris*, about 650 miles from the north lunar pole. *Mare Imbrium* fans will take a poor view of this! The main reason given for such a high latitude is that the temperature will not be excessive, though this argument appears of dubious value. The first part of the symposium ends with another Bonestell painting showing the three spaceships descending on their braking rockets.

Part II is mainly devoted to "The Exploration," written by Dr. von Braun and Dr. Fred Whipple. It is concluded that, for safety against meteors, the base should be set up in a deep crevasse. The cargo ship is dismantled, and tractor-driven vehicles unloaded for the use of the expedition, which will stay on the Moon for six weeks. Hydrogen peroxide-fuel oil turbines power the tractors.

The work which such an expedition could do is then described: amongst other things, artificial "moonquakes" would be set off by explosives, so that seismic records could be made. Perhaps the most impressive painting in the whole symposium is another Bonestell double-page spread showing a convoy of tractors moving over a vast lunar plain, illuminated by the greenish earth-light.

Another short article by Willy Ley, again illustrated by Fred Freeman, describes the interior layout of the lunar base. This would be constructed from the cylindrical hold of the cargo ship, which is divided into two sections and then lowered into a crevasse.

The last picture is the view from the abandoned cargo ship as the passenger craft take off on the return voyage, with the full Earth shining in the sky.

A fuller and more critical review of this material will be made in the *Journal* when it appears in book form, but it will already be gathered that the symposium is most impressive and extremely well presented. Many readers, however, will consider that it is highly misleading to suggest that the first lunar expedition will be on anything like the scale shown in *Collier's*. The enormous amount of equipment used, the special devices such as lunar tractors, and so on, could only become available after a great deal of experience of lunar conditions had been accumulated. If it was all designed in advance, the inevitable snags that always arise in practice would probably wreck the enterprise.

A truer assessment of the position has been made by von Braun himself in *Across the Space Frontier*: "The first attempt to land on the Moon will be a daring undertaking for a small crew travelling in a single ship."

The *Collier's* symposium, then, interesting and exciting though it is, must be regarded as depicting the twenty-first rather than the first lunar expedition!

A. C. C.

SOLAR SYSTEM NOTES—7

By Patrick Moore, F.R.A.S.

The Spring of 1953 is an excellent time for planetary observers. Mercury will be favourably placed as an evening star during the first week in March, and should be seen without difficulty; Jupiter is a splendid object during the first part of the night; Mars can still be seen low down in the evening sky, although it is now so far away that very little surface detail can be made out; Saturn rises before midnight—and for observers equipped with more powerful telescopes, Neptune can be found, near the bright star Spica in Virgo. But the most impressive object is undoubtedly Venus, a glorious "evening star" in the early part of the year and an equally glorious "morning star" during the summer. The stellar magnitude is about −4, which means that Venus is two magnitudes brighter than Jupiter, though of course it can never be seen against so dark a background.

Venus still remains a planet of mystery, despite all efforts to probe its secrets. The dense Cytherean atmosphere precludes us from observing the actual surface, and all that can be made out is a brilliant disk, marked here and there with extremely faint, diffuse shadings. Strangely enough, however, a number of drawings published during the past year have shown a central patch with linear features radiating from it, almost in the manner of Martian canals. How can these observations be reconciled with most of the rest?

It is true that Lowell, forty years ago, made some drawings of Venus that showed this appearance quite strongly; but it is important to remember that he stated definitely that there was no comparison with the markings on Mars. Most other well-equipped observers have completely failed to see the Cytherean "streaks," and, almost without exception, the drawings showing them have been made with telescopes of under 10 inches aperture. There are only two possible explanations. Either the eyes of the observers concerned are peculiarly sensitive to such detail, or else the detail does not exist, and the observers are deceived into transforming dusky nebulous shadings into hard lines. The present writer has experimented with two telescopes, a 12½-in. reflector and a 3-in. refractor, and, under very good conditions, has found the Cytherean shadings much harder and sharper with the smaller telescope!

Photography is not a great deal of help, though photographs taken in some wave-lengths do show light patches in the northernmost and southernmost parts of Venus that can also be made out visually from time to time. We cannot, however, say that these mark the poles (it was even suggested in a recent book that they were due to snow-caps), as the tilt of Venus' axis is still most uncertain, as is the length of the Cytherean day.

Irregularities in the terminator of Venus have also been seen during the present elongation (the "terminator" is the boundary between day and night hemispheres), and a particularly marked one was recorded in late December, 1952; but here again the observations are very difficult, and a slight shading of part of the disk may cause an adjacent brighter part to appear to project beyond the terminator.

The many observers who have been studying on Venus during the past few months nearly all agree that the disk is, as usual, more or less featureless, and marked only by vague, nebulous shadings here and there. This is only to be expected if the markings are atmospheric only; determination of the rotation period by ordinary visual observation seems an almost hopeless task, and it is probable that our nearest planetary neighbour will remain a world of mystery until the interplanetary age is with us, instead of "just round the corner."

ESCAPE TO INFINITY FROM CIRCULAR ORBITS

By Derek F. Lawden, M.A.

ABSTRACT

The problem of escape from a circular orbit to infinity, the final velocity being specified, using a minimum of fuel is considered. The conditions under which it is economical first to approach the attracting body are calculated.

The fact, discovered by Oberth,[1] that a considerable economy in fuel expenditure may sometimes be effected when escaping to infinity from a circular orbit by initially reducing velocity so as to curve in towards the centre of attraction and later increasing velocity at the point of closest approach to this centre, is often mentioned in the literature,[2,3] but the conditions under which this manœuvre is advantageous do not appear to be so well known. It will be proved in this note that, unless the velocity desired after escape has been effected is more than the escape velocity for a body stationary at any point of the circular orbit, it is more economical to escape directly via a single tangential impulse applied in the circular orbit.

To enable a body to escape from a centre of attraction μ/r^2 per unit mass, it must be placed in an orbit about this centre in which its total energy per unit mass, which is a constant of the orbit, is positive or zero. Here we are supposing that the potential energy per unit mass at distance r from the centre is $-\mu/r$. If the total energy of the body in its orbit is zero, it will escape to infinity along a parabolic arc. If its total energy is positive it will escape via a hyperbolic arc. At infinity the body's energy per unit mass will be entirely kinetic ($-\mu/r = 0$) and we shall suppose this quantity to be specified, e.g., by a statement of the velocity desired of the body subsequent to escape. Let E be this given energy. Then the problem is to transfer, with maximum economy of fuel, from a circular orbit of radius a to any orbit of total energy E per unit mass. We shall suppose the two orbits to be coplanar, it being almost self-evident that extra fuel will have to be expended if this condition is not satisfied. The orientation of the escape orbit can otherwise be selected arbitrarily to suit the circumstances without affecting the problem in any way, because of the perfect symmetry of the circular orbit.

Assuming at most a two-impulse transfer between the terminal orbits, it may be shown, by using the method and equations given in references (4) and (5) that optimum transfer between a circular orbit and any other orbit about the

same centre of attraction may be effected via an ellipse tangential at its apses to both the terminal orbits (Fig. 1). Impulses are applied tangentially at A and B, in the first instance to effect transfer from the circular orbit 1 into the intermediate elliptical orbit 2 and in the second instance to effect transfer into the final orbit 3.

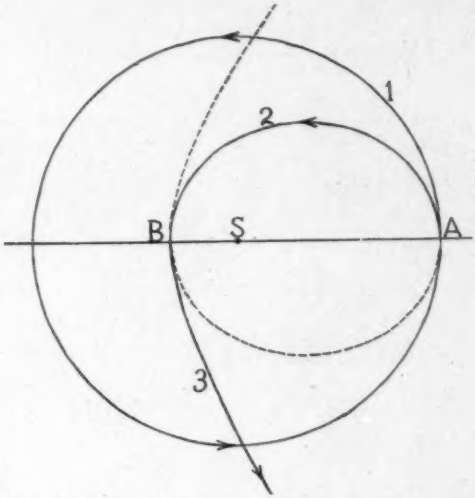


FIG. 1. Optimum transfer between a circular orbit and any other.

Let $AS = a$, $BS = b$. Since E is the given total energy per unit mass in orbit 3, if v_3 is the velocity in this orbit at B, $E = \frac{1}{2}v_3^2 - \mu/b$,

$$\text{i.e.,} \quad v_3^2 = 2(E + \mu/b) \qquad .. \quad .. \quad .. \quad (1)$$

If v is the velocity in the circular orbit, we have

$$v^2 = \mu/a \qquad .. \quad .. \quad .. \quad .. \quad (2)$$

The semi-major axis of orbit 2 is evidently $\frac{1}{2}(a + b)$ and hence the energy equation for motion in this orbit leads to the equations

$$v_1^2 = \mu\left(\frac{2}{a} - \frac{2}{a+b}\right) = \frac{2\mu b}{a(a+b)}, \qquad .. \quad .. \quad (3)$$

$$v_2^2 = \mu\left(\frac{2}{b} - \frac{2}{a+b}\right) = \frac{2\mu a}{b(a+b)}, \qquad .. \quad .. \quad (4)$$

where v_1, v_2 are the velocities in this orbit at the points A and B respectively.

If V is the characteristic velocity for this manœuvre, we shall have

$$V = (v - v_1) + (v_3 - v_2), \; b < a, \qquad .. \quad .. \quad (5)$$

$$V = (v_1 - v) + (v_3 - v_2), \; b > a, \qquad .. \quad .. \quad (6)$$

it being necessary to distinguish the two cases, since, if $b < a$, the initial impulse must be employed to reduce the rocket velocity so that it begins to curve inwards towards S, whereas if $b > a$, B lies outside the circular orbit and both impulses result in velocity increments.

Substituting for v, v_1, v_2, v_3 in equations (5) and (6) from equations (1)–(4) we obtain

$$\left.\begin{aligned} V &= \left(\frac{\mu}{a}\right)^{\frac{1}{2}} \left\{ \sqrt{2}\,(z+u^2)^{\frac{1}{2}} - \sqrt{2}\,(z+1)^{\frac{1}{2}} + 1 \right\}, \; z \geqslant 1, \\ &= \left(\frac{\mu}{a}\right)^{\frac{1}{2}} \left\{ \sqrt{2}\,(1-z)(1+z)^{-\frac{1}{2}} + \sqrt{2}\,(z+u^2)^{\frac{1}{2}} - 1 \right\}, \; z \leqslant 1, \end{aligned}\right\} \quad (7)$$

where $z = a/b$ and $u^2 = aE/\mu$. z is the ratio of the radius of the circular orbit to the distance of closest approach to S in orbit 3. u also is dimensionless. If w is the specified velocity at infinity in orbit 3, then $E = \frac{1}{2}w^2$ and hence

$$u = w/\sqrt{2}.v \quad .. \quad .. \quad .. \quad (8)$$

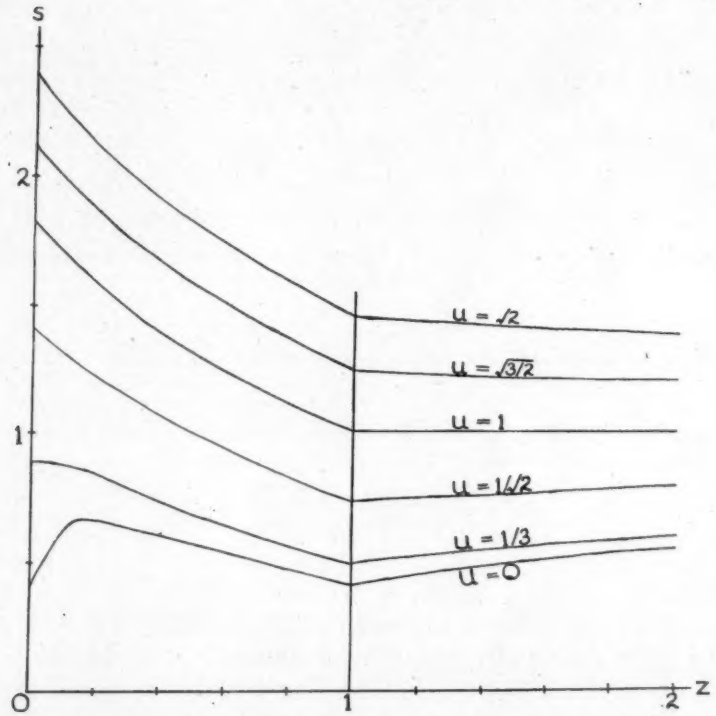


FIG. 2. Dependence of the characteristic velocity on the mode of escape.

Thus u is the ratio of the velocity at infinity in orbit 3 to the escape velocity for a stationary body at any point of the circular orbit.

If s is the ratio of the characteristic velocity to the velocity in the circular orbit, equations (7) may be expressed in the dimensionless form

$$\left.\begin{aligned} s &= \sqrt{2}\{(z+u^2)^{\frac{1}{2}} - (z+1)^{\frac{1}{2}}\} + 1, \quad z \geqslant 1, \\ &= \sqrt{2}\{(1-z)(1+z)^{-\frac{1}{2}} + (z+u^2)^{\frac{1}{2}}\} - 1, \quad z \leqslant 1. \end{aligned}\right\} \quad .. \qquad (9)$$

s has been plotted against z in Fig. 2 for the cases $u^2 = 0$, 1/9, 1/2, 1, 3/2 and 2. All graphs exhibit a discontinuity in slope at $z = 1$ and approach the line $s = 1$ asymptotically as z tends to infinity. For values of u less than 1, the graphs have a minimum at $z = 1$. For values of u less than 1/3, the graphs have a maximum for some value of z less than 0·2.

We can draw the following conclusions from Fig. 2:

(i) If the remaining velocity after escape has been effected is to be less than the escape velocity at a point on the circular orbit (i.e., $u < 1$), it is most advantageous to take $z = 1$. Orbits 1 and 2 then coincide and a single tangential impulse is applied at some point in the circular orbit.

(ii) If the remaining velocity after escape is to be greater than the escape velocity at a point in the circular orbit, optimum conditions can never be attained, but may be approached by letting z tend to infinity. In this case an impulse is applied tangentially at A (Fig. 1) so as to oppose the motion and bring the body into orbit 2. The closer the point of nearest approach B is to S, the more economical will be the escape manœuvre. The minimum fuel expenditure will, therefore, be determined by the distance of closest approach to S which may be permitted in practice. As z tends to infinity, s tends to unity and hence the characteristic velocity may be made to approach the velocity in the circular orbit. If z is large, equation (9) is approximately

$$s = \frac{u^2 - 1}{(2z)^{\frac{1}{2}}} + 1 \quad .. \quad .. \quad .. \quad .. \qquad (10)$$

indicating the manner in which s approaches unity.

(iii) The value $z = 0$ corresponds to a manœuvre in which the body is first transferred into a parabolic orbit by application of a tangential impulse and subsequently, when the body has escaped from S and has negligible velocity, a second impulse is applied to create the desired final velocity. The graphs show that this manœuvre is never more economical than that corresponding to $z = 1$, i.e., a single impulse escape.

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THE MARTIAN PROBE

By E. Burgess, F.R.A.S., and C. A. Cross, M.A.

(*Summary of a paper read to the North-Western Branch of the British Interplanetary Society, on September* 20, 1952.)

ABSTRACT

The projection of an automatic rocket into an orbit around Mars, from which it would telemeter data back to Earth, is shown to be several orders of magnitude simpler than any manned expedition. Such a rocket requires little more development of techniques than will be needed for the establishment of automatic earth satellites. On the other hand, the data which could be collected are shown to justify the proposal. Besides increasing knowledge of the planet Mars, the probe might be regarded as a pilot experiment to provide the experience needed for the successful execution of subsequent manned expeditions.

1. Orbits and Propulsion[1]

The velocity changes needed to transfer a body from the surface of the Earth into an orbit around Mars consist of three independent steps, which may be summed to obtain the characteristic velocity for the mission:

(*a*) The velocity needed to escape from the Earth's surface with sufficient residual velocity to convert the orbit around the Sun into a transfer ellipse cotangential with the orbit of Mars.

(*b*) The velocity needed at the nodal line to change the plane of the transfer orbit from the ecliptic to that of Mars.

(*c*) The velocity which must be removed from the body when it has fallen to the level of its orbit around Mars so that it will continue to revolve in the chosen orbit.

As neither planet moves in an exact circle around the Sun the characteristic velocity depends upon the time of the year chosen for the start from Earth. Take-off at Earth's perihelion is most advantageous in giving maximum aphelion distance to the transfer ellipse, but the greater eccentricity of the orbit of Mars makes it more important to consider the two extreme cases of travelling on semi-ellipses to reach Mars either at its perihelion or aphelion. Arrival at Mars' perihelion can be termed case I and arrival at aphelion, case II. The three velocity changes for these two extreme orbits are shown in Table I. The probe orbit round Mars has been chosen as a circle of 19,000 kms. radius to minimize perturbations by the natural satellites.

TABLE I

Orbit No.	Velocity change at Earth end	Velocity change at node line	Velocity change at Mars' orbit	Characteristic velocity
I	11·40	1·0	2·44	14·84
II	11·73	1·0	1·36	14·09

Although Orbit I makes smaller demands at departure from Earth, Orbit II needs much less velocity of change upon reaching the Martian orbit and shows a worth-while overall saving. This is because it is much better to have the

greatest transfer velocity at Earth where it may be obtained by only a slight increase in velocity at take-off. It follows from the general rule that, whenever any choice of orbit is possible the one should be chosen which has the greatest transfer velocity change at the planet with the greatest escape velocity.

The choice of Orbit II places a severe restriction on the launching date. This must be late in the August of 1973, or 1988 and so on at 15-year intervals. It means, too, that when contact has been made with Mars the planet has passed from good oppositions and is approaching distant ones which rather reduces the effective telemetering period per opposition. The probe will arrive at Mars nine months after opposition, and it must then wait in its orbit a further 19 months until the approach of the next opposition before important data can be telemetered. A beacon could, however, operate all the time. This type of time lag is, moreover, common to Orbit I and to all cotangential ellipse transfers.

The characteristic velocity for the Martian Probe using the best orbit, 14·1 km./sec., is thus only 2·3 km./sec. more than is needed to establish the 24-hour earth-satellite. Even so this requirement taxes our resources to the limit. Assuming a specific impulse of 325 sec., we need a three step rocket with mass ratios of 4·2 in each step together with five stages of tank jettison[2] in the first two steps. The delivery of half-a-ton of instruments into the orbit around Mars would need a rocket having an initial weight of nearly 700 metric tons.

2. Instrumentation and Control

A review of the present techniques of observing Mars shows that progress is restricted by our distance from the planet, by our atmosphere, and by our orientation (which prevents a view of the unilluminated hemisphere, or even a good view of the terminator).*

Automatic Earth satellite rockets would, by definition, operate successfully for some years before the Martian Probe. We may expect a thorough analysis from the vehicles of the total light from Mars. This will provide a great deal of new information on such matters as the composition of the atmosphere and its physical conditions. There will be no point in repeating this work from a position much closer to Mars. The earth-satellites will not, however, materially improve resolution of surface detail. The Mars Probe must, therefore, be justified as providing a method of examining surface detail with a high resolution, including the terminator and the unilluminated hemisphere of the planet.

From this point of view the orientation of the probe orbit around Mars is important. We are free to select any inclination of the orbit plane to the Equator greater than a certain angle which is zero if the probe arrives at Mars at the Martian solstice, and is 25° if at the equinox. The equatorial plane is, in any case, to be avoided, because then only the Equator itself can be seen vertically below and the poles would be completely unobservable. An orbit inclined at about 60° would seem best, but the plane of the Martian orbit offers considerable simplification in orientation problems and must be accepted on these grounds.

* Although, of course, Mars revolves on its axis and we can, therefore, see the entire planet, we are handicapped by the fact that we can only observe under full illumination.

By balancing the power needed to telemeter data[3] against the power available from a solar generator[1,4] we find that it should be possible to operate a telephony circuit for 4 months at a poor opposition and 9 months at the best, with a telegraphy circuit for the rest of the Martian year.

It is possible to transmit a high definition picture over a telephony circuit by facsimile methods.[5] By arranging to scan the surface of the planet optically as it passes beneath the probe we could cover a strip 300 km. wide with a resolution of better than $\frac{1}{2}$ km. At this rate the whole surface of the planet could be mapped in six weeks. Other data could be transmitted by pulse techniques during the flash-back interval of the scanner. These could profitably include the radar measurement of the vertical height of the probe (giving the height variations in the ground surface), the measurement of ground temperatures, absorbtion spectra of the area being scanned, and a number of internal data required for the control of the probe.

To achieve the objectives set forth an extensive telecontrol system must be envisaged. During the journey the optical scanner would be used to give the position of the probe in its orbit, so that the propulsion programme could be accurately carried out. When established in the satellite orbit, accurate control of the attitude of the probe must be retained, and this could be effected by the flywheel principle.[6] The use of jets would be restricted to the complete removal of angular momentum after each power manœuvre. In this way we obtain a control system which is maintained by the expenditure of energy alone, and could, therefore, be used as long as the rest of the probe was functioning.

The success of the Martian Probe will depend on the complete reliability of its critical components. They must be guaranteed against breakdown at least for the time needed to record one cycle of the seasons on Mars. The ultimate fate of the probe must, however, be a derelict hulk, hanging useless in its orbit until the time when a manned expedition will salvage and put to use its undamaged components.

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BRANCH MEETINGS

Seventh Annual General Meeting

The Seventh Annual General Meeting of the Society was held at Caxton Hall on Friday, December 5, 1952.

The Chairman, Mr. A. C. Clarke, opened the meeting by appending a few further points to his printed address, which had been circulated to all members beforehand in the *Annual Report*.

The next business was the approval of the audited Balance Sheet and

Accounts, which was proposed by Mr. R. A. Smith, and after seconding by Mr. C. Fleisher, was put to the meeting and carried unanimously.

The Chairman then referred to a minor alteration of the Society's Articles of Association which required consideration. The purpose of this alteration was to remove the requirement that members attending meetings should sign an attendance register, owing to the fact that the numbers attending meetings now made this course extremely inconvenient. Mr. H. P. Wilkins rose to propose the motion as a Special Resolution, which after seconding by Mr. G. P. Gilbert, was put to the meeting and carried unanimously.

The Scrutineers' report was then read concerning the election of four new Members of the Council by postal ballot.

The Report gave the number of ballot papers received as 532, and the names of those elected were:—

J. Foley P. A. Moore.
K. W. Gatland. G. V. E. Thompson.

Mr. Clarke said he felt very pleased to welcome Messrs. J. Foley and P. A. Moore, who would be serving on the Council for the first time, and would like to record his appreciation of the interest shown by all candidates who had allowed their names to be put forward.

A general discussion of the affairs of the Society during the past year then took place, during the course of which a number of suggestions were advanced, including a plea that further informal meetings be held.

Following the conclusion of the main business, the meeting then adjourned to see a number of colour slides of the Stuttgart Congress, and Mr. Clarke's recent tour of America, which included several scenes of the Mount Wilson and Palomar Observatories.

"Nuclear Energy and Spaceflight"

Speaking on the subject of nuclear energy at the meeting of the Midlands Branch on December 13, 1952, Dr. J. H. Fremlin, M.A., mentioned some interesting possibilities for its future use.

Though the main part of the talk was devoted to an explanation of nuclear energy—how it is made to do useful work, and how it is hoped to make it do more useful work in the future—Dr. Fremlin concluded by giving two examples of how it may be used as a power source for spaceflight.

Dr. Fremlin said that it would be very difficult, but not impossible, to do this. In the next decade or two, better progress would probably be made with chemical fuelled rockets, and nuclear energy might not show much advantage until the stage is reached where it will become possible to construct vessels in orbits round the earth. This will make possible the use of low thrust rockets, and nuclear energy may prove more easily adaptable to these.

One of Dr. Fremlin's examples illustrated this. A "fission reaction" pile of the type being developed today could probably be used to power an "ion" rocket, the pile energy being used to heat helium, which would drive a gas turbine coupled to an electrical generator. Dr. Fremlin thought that by

this means it should be possible to obtain a 100 ampere beam of mercury ions and to accelerate them through 250 kilovolts.

In his second example, Dr. Fremlin looked forward to the time when giant spaceships may be making interstellar voyages. He described a very hypothetical gaseous reactor which was virtually a miniature Sun. This reactor, which would use gaseous deuterium, was to be housed in a stainless steel sphere of 100 metres diameter, which would weigh over 4,000 tons. Its power output would be in the region of 3×10^7 kilowatts, and the reactor could possibly be used directly as a rocket, utilizing the reaction products as the jet, or the power may be converted to some other form of energy.

Midlands Branch Film Show, Saturday, April 18, 1953

The Midlands film show fixed for April 18, 1953, will feature *The German A4 Rocket* and *High Altitude Research*.

Admission will be by ticket only. Applications for tickets may now be made to the Branch Secretary, enclosing a stamped addressed envelope for reply.

Applicants should state whether they require tickets for the 3 p.m. or 6.30 p.m. performance.

Provisional Yorkshire Branch

A lecture was given to the Provisional Yorkshire Branch by Mr. Eric Burgess on December 20, 1952, at the Y.M.C.A. Building, Fargate, Sheffield. His subject was "The First Moon Rocket": he discussed the implications of mass-ratio, the step-principle, and the size and type of vehicle concerned.

The conditions the voyagers would experience were also described, and Mr. Burgess concluded by touching on the requirements for a voyage to Mars or Venus, and the value of a lunar base.

Twenty-seven members and visitors were present.

NOTES AND NEWS

Fourth International Congress on Astronautics

The Fourth International Congress on Astronautics is scheduled to take place at Zurich, Switzerland, from August 3–8, 1953. The programme has not yet been arranged but the titles of the lectures to be given will be announced in due course.

Members wishing to attend are strongly advised to book accommodation now, as there will be several important meetings in Zurich during the summer and it may be difficult to obtain reservations.

Bookings can be made through the S.A.A., Postfach 37, Baden, Switzerland, which is organizing the Congress, and application may now be made to the B.I.S. Secretary for copies of the necessary forms.

Panel of Lecturers

As was mentioned in the Annual Report, the Society now receives so many requests for lectures that only a small proportion of them can be accepted. It would be appreciated, therefore, if Fellows who are willing to give lectures would write to the Secretary informing him of:

(*a*) the areas in which they could speak, and

(*b*) any subjects in which they specialize.

The Society will then be able to form a panel of lecturers and will, it is hoped, be able to fill more of the requests than is possible at present.

Being on the panel will not involve any obligation—bodies contacting us will merely be referred to the speaker available in their district, so that arrangements can be made directly between the member and the requesting organization.

G.f.W. Changes

We are very pleased to hear that the G.f.W. has now been able to obtain a permanent office and paid clerical assistance—thus taking the step forward that the B.I.S. was able to make in 1952. Its new address is Stuttgart-W, Reinsburgstrasse, 54, Germany.

Herr Kölle has had to retire as secretary for the current year in order to complete his degree. Everyone will wish him the best of luck in his studies.

His successors will be Herr H. Gartmann as general manager, and Herr A. Fritz as secretary.

The Detection of Extra-Solar Planets

The 1952 October issue of *The Observatory* contains an interesting proposal by Otto Struve for the detection of planets of other suns—which, as he points out, is one of the burning questions of astronomy.

The present technique, with which K. A. Strand discovered the first extra-solar planet 61 Cygni C, is direct photography. Over a period of time, a binary system is photographed and a very accurate orbit obtained for the components. The presence of an invisible companion body—presumably a planet—can then be detected by the minute perturbations in the orbit.

This method is limited to nearby systems, and could not detect planets as small (!) as Jupiter. Nor could it detect objects ten times the mass of Jupiter, if they were more than an astronomical unit away from their parent star. Even if our sun were a binary star, therefore, none of its planets could be detected by extra-solar observers using this technique.

Struve suggests that there is no compelling reason why stellar planets should not, in some instances, be much closer to their parent stars than is the case in the solar system. It is known that *stellar* companions can exist at very small distances—in some cases, almost touching their primary.

A planet 1/50th of an astronomical unit (3,000,000 km.) from a star of solar mass would have a period of about a day and an orbital velocity of 200 km./sec. If its mass were equal to that of Jupiter, it would cause the observed radial velocity of the parent star to oscillate through a range of $\pm 0{\cdot}2$ km./sec.—a quantity perhaps just detectable with the most powerful existing spectroscopes. A planet with ten times the mass of Jupiter would be very easy to detect, as it could cause the star's radial velocity to vary through a range of ± 2 km./sec.

Eclipses might also be detected in the case of such a close planet. If its density were five times that of the star, it would cause a loss of light of 0·02

magnitude, which could be measured by modern photoelectric methods. The spectrographic test would be more accurate, but the photoelectric method could be applied to fainter limiting magnitudes.

Perhaps it should be pointed out that any planets detected by these means would be of no interest as possible abodes of life! Their surface gravities would be very high and their temperatures such that liquids could not exist on them, owing to their extreme closeness to their primaries. However, if such bodies could be discovered, it would indicate the presence of many others below the threshold of detection, and hence of a more terrestrial type.

Spaceflight at Schoolboys' Own Exhibition

Space-warfare, long a theme in science-fiction, broke out on a fortunately limited scale on December 31, 1952, when at the annual Schoolboys' Own Exhibition in London, the rival boys' magazines *Eagle* and *Lion* displayed competing spaceships. The *Eagle* ship, piloted by the intrepid Dan Dare, was the more convincing and certainly the more interesting. After passing through the airlock, one was taken on a rapid trip to the Moon by means of a back-projection film, and this ride was made surprisingly convincing by the movement of the floor. (We do not know if anyone was spacesick.) The passengers then had an opportunity of viewing some colourful dioramas of the planets—or at least *Eagle's* version of them!—before returning to Earth.

This spaceship attracted vast queues and a great deal of attention on press and radio, considerable prominence being given to the inevitable small boys who asked awkward questions of the harassed crew.

The *Lion* spaceship was considerably larger and displayed a most imposing quantity of dials, not to mention large tanks labelled "Hydrazine" and "Nitric Acid." Some of the fuel gauges, however, were a give-away as they bore the wording "Tail on Ground"! Nothing happened on this spaceship except a steady thumping noise like that of a low-speed diesel—a rather improbable sound, one would have thought, aboard such a vehicle. Once again there were large queues of would-be astronauts moving past the exhibit.

We do not know whether Hulton's or Amalgamated Press profited more from these expensive displays, but we feel that in the long run the B.I.S. will certainly be a gainer!

From the World's Press

The volume of Interplanetary reporting continues to increase—so much so that it is impossible to cover more than a small cross-section of the astronautical articles which now appear in the world's press. Four major events during the period July-December, 1952, helped to boost the normal flow. These were: the August publication of *Physics and Medicine of the Upper Atmosphere*, the September Astronautical Congress at Stuttgart, a paper read by Heinz Haber to the Chicago Centennial Convention of the American Society of Mechanical Engineers, and again in the same month, publication of *Across the Space Frontier*. Each of these dealt extensively with the biological and physiological hazards of spaceflight, stating the risks, the measures needed to combat them, and the unknowns awaiting further investigation and practical

solution. Unfortunately, owing to "selective" reporting (the lifting of material from its context), coupled with some journalistic misinterpretation, the dangers received much more publicity than the proposed safeguards. Indeed, the layman must have been left with the impression that a space traveller would need more lives than a cat to survive being suffocated, exploded, boiled in his own blood by lack of air, fried by solar heat, blinded by excessive sunlight, sunstroked by ultra-violet, de-natured by cosmic rays, riddled with meteors, and driven mad by weightlessness.

Of course these things *would* happen *if* one were silly enough to let them. Actually, the original discussions from which the various excerpts were made, quite clearly indicate that a proper vehicular and personal environment is envisaged; given which—and apart from, in the main, the unknown long-term biological effects of cosmic rays—a reasonable degree of immunity seems possible of achievement.

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The Nottingham *Evening News* and the Wolverhampton *Express and Star* of October 13 last reported that a number of New Zealand scientists and airmen have formed a group to investigate and "prove or disprove" the flying saucer mystery. We await developments with interest, but would like to remark that talking things *into* existence is much more easily done than talking them *out* of existence. For which reason alone it seems probable that flying saucers will remain airborne for quite a while yet.

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Under the heading *Space Rats and Good Guys* the Editorial Diary of the *Glasgow Herald*, of October 17 last, opens with the statement that "The Rev. Paul Kiehl, executive vice-president of Church Craft Inc., a firm who have hitherto specialized in the production of lantern slides and films of Bible stories, has said in an interview:—'I think that space is going to be a hot number. We feel we've got a good thing.'"

Astronauts have felt this for a long while, but some modern extensions of activities make us rather apprehensive as to what is coming next! Our anxiety is not allayed by the *Glasgow Herald's* prophecy that "The instruction contained in the finding of Moses and in the wanderings of the Children of Israel is now to be reinforced and modernized by the production of three-dimensional colour slides of the exploits of Buzz Cory, commander-in-chief of the Space Patrol."

If, as seems probable, this is going to result in an apostolic picturization of interplanetary battles between "good guys" and "space rats," then, as Sam Goldwyn might say, "include us out of it."

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The fact that the B.I.S. has quadrupled its membership since 1948, to 2,010 at September 30, 1952, was—to our knowledge—noted by no less than 36 British papers alone. The majority considered this news of sufficient importance to warrant special headings, such as "Looking up," "Rocketing,"

"Sky High," whilst the *Huddersfield Examiner* of November 19, in a jocular but sympathetic half-column, concluded by prophesying that membership of the B.I.S. will increase by leaps and bounds. If the present level of publicity is maintained, it certainly should.

* * * *

A pat on the back. . . .

"For sheer audacity the astronauts have no peers in the history of technology. Man looking up and boldly proclaiming 'some day we'll cross that black chasm and roam through the universe'—it seems incredible. . . . Some harsh things have been said about the stupidity and the cruelty of man, but when he claws the heavens in his epic moments and thinks of conquering the immensity of space the tiger and the ape in him is transformed into a defiant Prometheus tearing at the chain that binds him to this rock of an earth." (*New York Times*—7.9.52.)

A kick in the stomach. . . . ?

The *Montreal Daily Star* of September 17 last mentions an interplanetary trend in catering. For example, McCarthy's Steak House, Manhattan, which now "boasts such items as guided mussels, Venus schnitzel with Mars potatoes, egg planet and flying sausages with grav(it)y. Customers who like a drink beforehand are sure to be happy with a Marstini."

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The trade publication *American Aviation* of November 10 reveals Soviet progress in rocket aircraft. It is stated that "development models" already flown weigh about 15,000 pounds, are 38 feet long, have a span of 25 feet, and are capable of a top speed of 1,700 m.p.h. at altitudes upwards of 100,000 feet, and remarks that "although hitherto they have been tested in the Moscow area—they are built at Poberesje, a research centre north of the capital—test flying will henceforth be carried out at Tomsk in Siberia. . . ." Advance to a speed of 2,500 m.p.h. at 200,000 feet is apparently expected to result from development work now being given top priority.

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Cuttings from the Glasgow *Sunday Mail* of November 9 and *The Times* of December 5 furnish glimpses of Russian astronautics. The *Sunday Mail's* source of information was the Soviet-controlled East Berlin newspaper *Taegliche Rundschau*, from which drawings of a spaceship were reproduced. Unfortunately, neither the pictures nor the description are very illuminating. However, it is apparent that the vessel consists of a massive torpedo-shaped forward section, at the rear of which is a retractable-winged glider with two large spherical "oxygenation fuel tanks" attached to the tail. The merits of this arrangement are somewhat obscure. However, taken at face value, it seems to fall into that category of empirical visualization which R. A. Smith has graphically captioned "the sleek and deadly supersonic submarine class," and as such cannot be regarded as a serious engineering proposition.

If this is the best that Soviet scientists can do—which is most unlikely—then they still have a lot to learn from the West, and *The Times'* fears that the red flag will be hoisted on the Moon within the next fifty years are groundless. Be that as it may, it is interesting to learn that Soviet astronautical thought parallels that of the Western world as regards general *modus operandi* and in the matter of artificial satellites—which latter, according to *The Times*, "will be launched from an extensive 'cosmodrome' at Kaluga."

Commenting, *The Times* says ". . . it is difficult to see what benefits would accrue to the human race if the firmament were crowded with pseudo-heavenly bodies, whizzing round and round our planet and emblazoned with the emblems of mutually antipathetic States. It would be almost sure, as nannies say, to end in tears." . . . True—so why not sensibly avoid trouble by agreeing to cosmopolitanize man's cosmic aspirations?

* * * *

During early September, British papers carried many reports of the B.A.A. paper, given in Belfast by Dr. S. F. Singer, dealing with high-altitude physical research by means of rockets and advocating the early construction of an Earth-satellite-vehicle, at least of small, instrument-carrying type.

At about the same time, there were also many Press items, both here and abroad, dealing with the Third International Astronautical Congress at Stuttgart. Coverage was rather less extensive than for the previous year's meeting in London, but once again the accounts were couched almost universally in friendly, sympathetic, and serious terms. It would appear that the days are gone when editors and reporters regarded interplanetary flight as being merely an invitation to facetiousness!

The *New York Times* appeared to be critical of von Braun's Stuttgart speech, in which he referred to the stultifying effect of government control of research, for military ends and against severe dead-lines in regard to time. "These are sharp words from a man who has been maintained in the United States almost since the end of the war, and they criticize the whole system . . . of which Dr. von Braun is a part," said the N.Y.T. We cannot help feeling that much of this disapproval results from taking von Braun's words from their whole context; what he actually said is known to be true by anyone who works on military research projects, however much they accept the unhappy necessity of them (as we are sure von Braun does).

We are even more sympathetic towards von Braun for being the target of the following atack, in characteristically undignified tone, from the other side of the Iron Curtain! It is reproduced from a July report of the B.B.C. Monitoring Service:—

> "THE EARTH SATELLITE PROJECT was discussed by Cheplygin in a *Red Star* article entitled 'Interplanetary Ravings.' Recalling Gogol's 'Notes of a Madman' and its story of Poprishchin's obsession with the idea of a man-made Moon, he averred that this idea has been taken up by another madman —Forrestal, U.S. Defence Secretary. *Collier's* had now revived the idea in a series of special articles urging that the U.S.A. should quickly take control of interplanetary space in order to set up a military base in it.

'Obsessed with the mania of greatness they (the authors) dream of the possibility of directing from this moon, missiles, guided by radar and filled with atomic explosives, to be aimed with deadly accuracy at any objective on the Earth. With the delight of a frenzied monster, Wernher von Braun savours the thought of how convenient it will be for the American interplanetary pirates, sitting on their artificial moon, to scatter over peaceful States a hail of atomic bombs. . . . He imagines how the American Intelligence Service will be able to peep lasciviously at the countries of the universe as through a keyhole.' The articles had even suggested that there was some danger of the Soviet Union seizing control of interplanetary space. 'It is quite understandable why the American reactionary Press publishes this interplanetary nightmare. . . . It is trying to distract people's attention from America's aggressive actions on Earth. The American imperialists are howling for the Moon because things are not going too well for them over here'."

* * * *

During the summer, wide circulation was given in a number of newspapers to a report that a V.2 had entered an orbit round the Earth and failed to return. The B.I.S., when consulted rather late in the day, made clear that the rumour was nonsense, but it still turns up from time to time in unenlightened quarters. Perhaps the best comment so far published is the following, which we reprint from *The Drawing Office Announcer*, No. 44 (November 4, 1952):

"Some Not So Scientific Comment

"A somewhat similar incident occurred on the south coast of England in August of this year. Whilst cliff climbing a brace button was catapulted into space (albeit involuntarily) and this also has not been seen or heard of since that date. With customary British indifference to the scientific possibilities of this event, it has not previously been considered that the button describes circles in space, but the thought now arises that not only may it be so doing, but perhaps in a contra rotational direction to that of the rocket.

"What will happen if the button and the V.2 meet in head-on collision in the outer void? Will the rocket reverse the button or will the rocket be diverted tangentially from the curvature of said button?

"As similar incidents have doubtless occurred from time to time in man's history, may it not be within the realm of possibility for a future generation of explorers to find a V.2 embedded in the sands of time wearing a complete set of brace buttons—much to the mystification of Boffins of that era yet to come?—*'Debunkem'*."

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Professor Picard, the stratosphere balloonist, is attempting to raise $250,000 for a project to climb 100,000 ft. high in a two-seater cabin raised by 80 balloons, each of 250 ft. diameter. The object would be to obtain clear photographs of Mars during the favourable approach in 1954. Some newspapers reported this item, not very intelligently (and—to Picard—rather insultingly), as a proposal to fly *to* Mars by balloon!

The *New Yorker* of August 30, described a visit to the Hayden Planetarium's interplanetary show. While there, their representatives found a copy of the B.I.S. Journal, and "were doing all right" until they met some of Dr. Shepherd's mathematics, in his paper "Interstellar Flight." This, we were told, ended their browsing; the profound conclusion of the "New Yorkers" was that "Outer space seemed remarkably like inner space."

* * * *

There have been several reports (e.g., the *News-Chronicle* for September 3) to the effect that the Government's plans to economize as much as possible on the rearmament programme may include a shift in emphasis on to newer and more effective weapons of an advanced technical nature. In other words, whatever happens, the research and development work on guided missiles is likely to be continued on the present, or even on an intensified, scale.

We were surprised, however, to see how many papers (just prior to the successful explosion in October of the first British atomic weapon) swallowed the rumour that it was to be fired in a rocket, all the way from Woomera to the Montebello islands!

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A toy rocket shaped like a V.2, costing about £2 and capable of repeated firings to 85 m.p.h. and several hundred feet in the air, was shown at the Frankfurt autumn fair. Refills of the powder charge cost 1s., and a safe landing is assured by a parachute!

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Everybody's Weekly, for September 6, printed an article on guided missiles by Gen. Sir Frederick Pile, which was interesting for an account (with photograph) of an early British war-time attempt at a guided anti-aircraft rocket. The product of a small research station at Walton-on-the-Naze, the missile consisted of a streamlined body with wings and tail surfaces, propelled by six standard solid rockets fitted inside housings faired into the "fuselage." Performance was said to be erratic, but eventually the missile "was held under control for a matter of 1½ seconds."

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Successful test flights, starting in June, are reported for a new French jet fighter, the S.O.6025, fitted with an S.E.P.R. auxiliary liquid-propellant rocket motor. The aircraft was developed from the Nene-engined "Espadon," and the test pilot was Jacques Guignard.

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The following news has been received from Beachcomber via the *Daily Express*:—

Mouse goes up 1,146 *miles*

No date has been announced for the start of the Strabismus moonrocket. All will depend on tides, winds, air-currents, nebular conditions, interstellar temperatures, planetary weather, and stratospheric upheavals. A mouse sent up to a distance of 1,146 miles yesterday, with recording instruments attached, came back with radio-active whiskers and a wild look in its eyes. Later it was sick.

ABSTRACTS

Edited by J. HUMPHRIES

Abbreviations of titles of journals were given in the May, 1950, issue of the *Journal*, and addenda have appeared in subsequent issues. The following is a further addendum to the list:—

J. Amer. Med. Ass.	Journal of the American Medical Association.
Mem. Soc. Roy. Sci., Liège.	Mémoires de la Société Royale de Science, Liège.
Monatsh. Chem.	Monatshefte für Chemie und verwandte Teile andere Wissenschaften.
Publ. Astr. Soc. Pacif.	Publications of the Astronomical Society of the Pacific.

Many of the articles noted are available on loan to members resident in the British Isles. Requests should be addressed to J. Humphries, 97, Churchill Avenue, Southcourt, Aylesbury, Bucks.

AERODYNAMICS

See also Abs. No. 90.

(59) **A solution of the laminar boundary-layer equations for a compressible fluid with variable properties, including dissociation.** L. L. MOORE. *J. Aero. Sci.*, **19**, 505-518 (*Aug.*, 1952).

Evaluation of the skin-friction and heat transfer characteristics is made for a flat plate in compressible flow for a Mach Number range 1 to 20. Both the insulated plate without radiation and the plate with heat transfer are considered. (15 *refs.*)

AIRCRAFT

(60) **Oops! There goes a record!** S. BANGS. *Interavia*, **7**, 572-575 (*Oct.*, 1952).

Description of Bridgeman's flights in the Douglas "Skyrocket."

ASTRONAUTICS

(61) **Astronautics and relativity.** C. MAUGUIN. *C.R. Acad. Sci. (Paris)*, **234**, 1,004-1,007 (*March* 3, 1952), 1,329 (*March* 24, 1952).

(*In French.*) The relationship between the distance x (in light years) travelled by a hypothetical vehicle, in a system in which the vehicle is at rest at zero time and the time τ (in years) measured in the vehicle, is derived for the case in which the vehicle is moving with a constant acceleration of 950 cm. sec.$^{-2}$ (measured with respect to a system instantaneously at rest relative to the vehicle at any instant). In this case $x = \cosh \tau - 1$, the corresponding time which elapses in the fixed system is $t = \sin \tau$.

(62) **Will we reach the Moon by 1970?** A. H. DELSEMME. *Ciel et Terre*, **68**, 137-144 (*June*, 1952).

(*In French.*) General discussion of the problems.

(63) **Design for zero "g."** K. W. GATLAND. *Flight*, **51**, 774-775, 779 (*June* 27, 1952).

Description of the Smith-Ross design for a man-carrying rocket for physiological research in near space.

(64) **Space-flight Conference.** J. HUMPHRIES. *Flight*, **62**, 378 (*Sept.* 19, 1952).

Brief review of Third International Congress on Astronautics.

(65) **Chemical problems of space-flight.** F. HECHT. *Natur u. Technik*, **6**, 270-273 (*Oct.*, 1952). (*In German.*)

Text of the lecture delivered at the Third International Congress on Astronautics. Delineates all the problems connected with propellants, materials of construction, air supply, biochemistry, etc.

(66) **Inside the Moon ship.** W. LEY. *Collier's*, 56-57 (*Oct.* 18, 1952).

Description of the living quarters.

(67) **The journey.** W. VON BRAUN. *Collier's*, 52-56, 58, 60 (*Oct.* 18, 1952).

Popular description of the vehicles needed for a journey from an artificial satellite to the Moon and return.

(68) **Inside the lunar base.** W. Ley. *Collier's*, 46-47 (*Oct.* 25, 1952).
Description of underground base.

(69) **The exploration.** F. L. Whipple and W. von Braun. *Collier's*, 38-40, 42, 44-46, 48 (*Oct.* 25, 1952).
The exploration of the Moon's surface, including the investigation of a possible atmosphere and methods of examining its crust and core to determine its origin.

(70) **The Martian probe.** E. Burgess. *Aeronautics*, **27**, 26-33 (*Nov.*, 1952).
Consideration of the orbits and construction of an unmanned robot vehicle to circle Mars and telemeter back scientific information. Size of vehicle to carry 500 Kg. of equipment would be about 640 tons.

(71) **Flights to the major planetary systems.** H. B. Ketchum. *J. Space Flight*, **4** (9), 1-3 (*Nov.*, 1952).
Consideration of flights to the outer planets.

(72) **Some problems of interplanetary travel.** J. M. J. Kooy. *Ingenieur*, **64** (46), 37-45 (*Nov.* 14, 1952). (*In Dutch.*)
Calculation of satellite vehicle and escape vehicle. Discussion of overall mass-ratio as a function of exhaust velocity and acceleration.

(73) **The Third International Congress on Astronautics.** J. Humphries. *Aircraft Engng.*, **25**, 373-375 (*Dec.*, 1952).
Abstracts of the papers delivered.

ASTRONOMY

(74) **On the possible existence of plant life on Mars.** O. V. Troitskaya. *Astronomicheskii Zhurnal*, **29**, 57-62 (*Jan.-Feb.*, 1952). (*In Russian.*)

(75) **Recent observations of Mars.** G. Fournier. *Astronomie*, **66**, 355-358 (*Sept.*, 1952). (*In French.*)
General notes on the recent apparition.

(76) **Jupiter IX and XII.** S. Herrick. *Publ. Astr. Soc. Pacif.*, **64**, 237-241 (*Oct.*, 1952).
Mathematical treatment of the orbits.

(77) **Meteorites and cosmic rays.** S. F. Singer. *Nature*, **170**, 728-729 (*Nov.* 1, 1952).
The production of helium in meteorites by the action of cosmic rays and its effect on age determination of meteorites.

ATMOSPHERE

(78) **Preliminary report on atmospheric ozone measurements from rockets.** J. A. van Allen and J. J. Hopfield. *Mem. Soc. Roy. Sci., Liège*, **12**, 179-183 (1952).
Technique and results from 25-60 km.

(79) **The average atmosphere up to 220 km.** R. J. Havens and H. E. Lagow. *Mem. Soc. Roy. Sci., Liège*, **12**, 185 (1952).
Basic physical data tabulated up to 160 km. in 10 km. steps, based on observations from 10 rocket flights at White Sands.

BIOLOGY AND MEDICINE

See also Abs. Nos. 63 and 74.

(80) **Medical research in development of manned rocket flight.** H. Haber. *U.S. Cen. Air. Docum. Off* (*N-AF*) *Tech. Data Digest*, **17**, 12-13 (*Feb.*, 1952).

(81) **Medical aspects of flight above the atmosphere.** P. A. Campbell. *J. Amer. Med. Ass.*, **150**, 4-6 (*Sept.* 6, 1952).
General review of the problems involved.

CHEMISTRY

See also Abs. No. 65.

(82) **Spontaneous decomposition of hydrogen peroxide.** E. Abel. *Monatsh. Chem.*, **83**, 422-439 (1952). (*In German.*)
Review of literature shows mechanism to be independent of any extraneous influences, such as reducing agents and catalysts.

(83) **Measurements on the equilibrium between hydrazine and water in the vapor phase.** D. ALTMAN and B. ADELMAN. *J. Amer. Chem. Soc.*, **74**, 3,742-3,744 (*Aug. 5*, 1952).

(84) **Vapour-liquid equilibrium. VIII. Hydrogen peroxide-water mixtures.** G. SCATCHARD, G. M. KAVANAGH and L. B. TICKNOR. *J. Amer. Chem. Soc.*, **74**, 3,715-3,720 (*Aug. 5*, 1952).

(85) **Behaviour of liquid hydrocarbons with white fuming nitric acid.** C. H. TRENT and M. J. ZUCROW. *Industr. Engng. Chem.*, **44**, 2,668-2,673 (*Nov.*, 1952).

Determination of the temperature-time curves for 20 hydrocarbons reacted with anhydrous nitric acid. The hydrocarbons chosen were typical of those found in the gas turbine fuel J.P.3. (17 *refs.*)

(86) **Kinetics of decomposition of nitric oxide at elevated temperatures. II. The effect of reaction products and the mechanism of decomposition.** H. WISE and M. F. FRECH. *J. Chem. Phys.*, **20**, 1,724-1,727 (*Nov.*, 1952).

PHYSICS

See also Abs. Nos. 61 and 104.

(87) **An analysis of an X-ray absorption method for measurement of high gas temperatures.** R. N. WELTMANN and P. W. KUHNS. N.A.C.A. Tech. Note No. 2580 (*Dec.*, 1951).

The suggestions for the instrument are based largely on theoretical work. It could be used over a wide temperature range and especially over 2,000° K, in the dissociation region.

(88) **Pt. I. Tabulated thermal data for hydrocarbon oxidation products at high temperatures. Pt. II. The effect of dissociation on rocket performance calculations.** A. B. P. BEETON. *R. and M. No. 2542*, H.M.S.O. (1952).

Tables given of total heat and entropy of H_2O, CO_2, O_2, CO, H_2, OH, O and H for temperature range 1,500-4,000° K. Equilibrium constants also given. In Pt. II the combustion temperature for a 3 to 1 mixture ratio of oxygen and hydrocarbon is found to be reduced by 300° C by dissociation. Specific impulse is also reduced by 10 secs.

(89) **Heat transfer in a nozzle at supersonic speeds.** O. A. SAUNDERS and P. H. CALDER. *Engng.*, 281-284 (*Aug.* 29, 1952).

Experimental results given which agree well with flat-plate theory.

(90) **On heat transfer over a sweat-cooled surface in laminar compressible flow with a pressure gradient.** M. MORDUCHOW. *J. Aero. Sci.*, **19**, 705-712 (*Oct.*, 1952).

A simple expression is derived for the normal injection velocity distribution theoretically required to maintain a given uniform temperature along a porous surface in the laminar boundary-layer region of a compressible flow with a given velocity distribution outside of the boundary layer.

(91) **Rocket determination of the ionization spectrum of charged cosmic rays at $\lambda = 41°$ N.** G. J. PERLOW, L. R. DAVIS, C. W. KISSINGER and J. D. SHIPMAN. *Phys. Rev.*, **88**, 321-5 (*Oct.* 15, 1952).

Results obtained from a V.2 experiment.

(92) **Viscosities of several liquids.** D. M. MASON, O. W. WILCOX and B. H. SAGE. *J. Phys. Chem.*, **56**, 1,008-1,010 (*Nov.*, 1952).

Viscosities of ethylenediamine, ethylenediamine hydrate, hydrazine and isopropylamine in liquid phase over temperature ranges 30-210° C, 30-170, 10-80 and 0-180 respectively at pressures from bubble point to 250 atmos. Viscosities in liquid phase of commercial samples of R.F.N.A., W.F.N.A. and furfuryl alcohol over temperature ranges 10-120° C, 10-120 and 30-130 respectively, also given. (14 *refs.*)

PROJECTILES

(93) **The calculation of step-rockets.** M. P. BLANC. *Mém. Artill. Franç.*, **26**, 705-734 (1952). (*In French.*)

Deals with single, two-stage and multi-stage rockets. General equations are derived and, in particular, it is shown that, for a given number of steps and given all-up weight, there is an optimum arrangement for maximum performance. This is when the true mass ratio at the beginning of each step is a constant. Tables and examples are given.

(94) **Some general aspects of missile testing.** J. H. ZARBISKIE. *Soc. Automot. Engrs. Prepr.* No. 733, 6 pp. (*Jan.*, 1952).

(95) **Trajectories of beam-rider rockets with gas-flow control.** E. PERRET, E. ROTH, R. SÄNGER and H. R. VOELLMY. *Z. angew. Math. Phys.*, **3**, 241-258 (*July* 15, 1952). (*In German.*)
Assuming a straight course of the target, the trajectories of beam-rider anti-aircraft missiles are computed for different launching intervals. Three different guiding systems are discussed by showing the necessary steering movements.

(96) **Development of the guided missile.** K. W. GATLAND. *Flight*, **52**, 68-70 (*July* 18, 1952).
A survey of the economics and strategy of the use of long-range rocket missiles.

(97) **N.A.C.A.'s rockets gather data for missile design.** J. A. SHORTAL. *Soc. Automot. Engrs. J.*, **60**, 17-19 (*Nov.*, 1952).

ROCKET MOTORS

(98) **The pressure relationships in a tubular combustion chamber.** C. WAGNER. *Off. Chief Ord. Res. and Dev. Rept. Fort Bliss Rept., A*-17, 9 pp. (*Feb.*, 1946). (*In German.*) [Also available as *Ministry of Supply T.P.A.*3/*T.I.B. Translation No. T.* 3912, 7 pp. (1952).]
Derives equations for the pressure along a tubular combustion chamber fitted with a Laval nozzle.

(99) **Bazooka rocket motor testing now fully automatic.** H. E. STEIN. *Iron Age*, **169** (12), 100-102 (*Mar.* 20, 1952).
Describes the use of a standard 12-station rotary press for testing bazooka rocket tubes up to a pressure of 25,000 p.s.i. 600 tubes/hour can be handled.

(100) **Combustion chamber jacket with alternate cooling passages of fuel and oxidizer.** R. H. GODDARD. *U.S. Pat. No.* 2,591,421 (*April* 1, 1952).

(101) **Liquid fuel and oxidizer jacketed combustion chamber with axial conical fuel spreader.** R. H. GODDARD. *U.S. Pat. No.* 2,591,422 (*April* 1, 1952).
Arrangement for extra combustion in the convergent part of the nozzle.

(102) **Rocket motor pumped supersonic wind tunnel.** A. J. NERAD. *U.S. Pat. No.* 2,592,322 (*April* 8, 1952).
Use of rocket with augmentor to produce gases for a wind tunnel.

(103) **Snarler.** *Flight*, **52**, 92-93 (*July* 25, 1952).
Description of the Armstrong Siddeley "Snarler"—liquid oxygen/methanol, turbo-pump rocket, giving 2,000 lb. thrust.

(104) **High temperature thermodynamic processes.** F. E. OSBORNE. *Aircraft Engng.*, **24**, 294-297 (*Oct.*, 1952).
Generalized treatment with particular reference to the flow through rocket nozzles and the determination of specific impulse.

(105) **Improvements relating to rocket motors.** DE HAVILLAND ENGINE CO., LTD., F. B. HALFORD, A. V. CLEAVER and E. B. DOVE. *Brit. Pat. No.* 680,717 (*Oct.* 8, 1952).
Use of part of the turbine gas in the combustion chamber and pressure device to delay injection of propellants until precombustion pressure is sufficient.

(106) **Improvements relating to rocket motors.** DE HAVILLAND ENGINE CO., LTD., F. B. HALFORD, A. V. CLEAVER and E. B. DOVE. *Brit. Pat. No.* 680,718 (*Oct.* 8, 1952).
Use of an annular precombustion chamber around main injector.

WANTED.—B.I.S. *Journals*, Vols. 1–7 (1934-1948), and also 1949 *Annual Report*.—Dr. I. H. D. Johnston, 49, Spottiswoode Road, Edinburgh, 9.

BOOKS AND PERIODICALS on astronautics bought and sold.—Astronautica, 31, Brooklands Gardens, Hornchurch, Essex.

WANTED.—Back files of B.I.S. *Journals*, etc. Offers to The Manager, Mapleton House, 5412–16, Avenue, Brooklyn, 4, N.Y., U.S.A.

REVIEWS

Das Marsprojekt

(By W. von Braun. 82 pp. Umschau Verlag, Frankfurt am Main, 1952. DM5.)

In the introduction, Dr. von Braun states that the aim of this work is to prove that the technical means of the present time are sufficient to tackle such an enormous task as an expedition of 70 people to Mars. His calculations are based on the use of the propellant combination nitric acid and hydrazine for all stages of the journey.

The book is divided into three parts, each dealing with the equipment necessary for completing one of the main stages of the expedition:

(A) The three-step cargo rockets for accumulating the parts of the spaceships, propellants, equipment and crew for the actual space journey, in an orbit 1,730 km. above sea-level. The relevant data for this stage are as follows:

Number of cargo ships: 46.
All-up weight of each ship: 6,400 tonnes.
Number of ascents: 950.
Time for all cargo journeys: 9 months.

(B) The spaceships for travel between Earth orbit and Mars orbits, carrying food, equipment and propellants for 70 persons, and three landing boats.

Number of spaceships: 10 (3 abandoned in Mars orbit).
All-up weight of each ships: 3,700 tonnes.
Time between start from and return to Earth orbit: 2 years, 239 days.

(C) The landing boats for landing 50 persons with equipment for a stay of 400 days on the surface of Mars:

Number of boats: 3 (1 abandoned on surface of Mars, 2 abandoned in Mars orbit).
All-up weight of each ship: 200 tonnes.

In each section, tables are presented giving the results of the calculations, e.g., trajectory parameters, weight estimates, main dimensions. The text describes the assumptions made by the author and the equations used in computing the values given in the tables.

Looking at the tables in Section A, the innocent reader is rather shocked by the enormous magnitude of some of the figures. The all-up weight of the cargo rocket of 6,400 tonnes approaches the weight of a medium-size ocean steamer. The thrust of the first stage is 12,800 tonnes and needs 56 tonnes/second of propellant to be maintained at that level. It may be possible to realize these enormous figures but one can have doubts as to whether it is possible with a propellant/structure weight ratio of 0·146, as given in the table. Here one comes to the weak point of the attempted proof—the weight estimates. The author stresses the point that he has tried no optimum calculations, and, therefore, considers that he is keeping on the pessimistic side of the picture. But surely this can apply only to those data that can be approached mathematically?

We may consider such a project calculation as a balance-sheet, one side

containing all those values that we wish to achieve such as performance data, the other side showing the price to be paid—in our case the weight. Is there any point in making painstaking efforts to obtain the highest possible accuracy on the "income" side if the "expenditure" side can be done only by rough guesswork? This is precisely what the author has done. The whole text of the book is devoted to verifying all of the results, except the weight figures, which have to be accepted by faith. The only explanation as to how the structural weights of, for instance, the cargo-ship were assessed, is contained in one short paragraph in which the author states that these figures came partly from experience with smaller rockets and aeroplanes and partly by approximate structural calculations using a rather high safety factor. Surely this approach is not sufficient to obtain the accuracy required for the proof at which the author aims.

It is well known that a small error in the weight calculation has a great effect on the payload of an aircraft, and in rocket design, especially in this case, where the payload is only 39 tonnes (i.e., 0·61 per cent. of the all-up weight of the cargo-ship). A more appropriate method would have been to attempt a detailed design of the vehicle, which in itself would have been a tremendous task. That this has not been attempted can be gathered from the text, in which the description of many of the arrangements are very loose. Sometimes a choice of arrangements fulfilling the same purpose is given. Two cases will be quoted. The size of the motor compartment of the first step is given as 6 metres long by 20 metres diameter and contains some rocket motor arrangement giving 12,800 tonnes total thrust; the author recommends a multiplicity of venturis in order to keep the venturi length to a reasonable size. But no number is given and no mention as to whether the venturis are connected to separate combustion chambers or to a single one. Taking the V.2 as the unit size, for example, the number required would be about 500, which is out of the question. On which number did the author base his weight assessment? Surely the weight would not be the same for different arrangements. Furthermore, it is not mentioned how the cooling difficulties arising from the increased chamber wall thickness for the larger units have been overcome. This criticism may be considered as delving too deeply into details, but if the pumping pressure has to be considerably increased in order to give the required pressure head for more intense cooling, then the whole pay-load might be eaten up by the higher propellant consumption of the pump drive.

The other case concerns the wings of the third step of the cargo-ship which, having a span of 52 metres to an area of 366 square metres, are described as being either retractable, or rigidly fixed to the fuselage, or as made in parts, carried up to the orbit in the cargo space and there mounted on the fuselage just before the return journey. Again, it is beyond doubt, that the weights of the three arrangements will be quite different. Another major problem which has apparently not been considered is the influence of the very high temperatures (estimated by the author at 700–1,000° C.) on the wing structure. It is very unlikely that such a wing can be designed using conventional methods; assessing its weight by comparison with existing aircraft wings can therefore never lead to an acceptable result.

But even a weight calculation based on a thoroughly designed project will contain an error of ± 10 per cent. as experience in all branches of engineering has shown again and again, which means ± 80 tonnes in the case of the cargo vessel with its total structural weight of 800 tonnes. The possible error is about twice as great as the pay-load!

Similar considerations apply to the vehicles for stages B and C of the journey, but it is not intended to go into further detail, except for the landing procedure on Mars which is worth mentioning. The thin atmosphere necessitates the very high landing speed of 196 km./hr. (even then the wing area is 2,810 square metres and the span 153 metres!), which demands a prepared landing field, which will be located near the Equator, as the return journey to the orbit has to be made from the landing point. One of the landing boats can be sacrificed and is able to land on one of the snow-covered polar caps using skids instead of wheels. The crew disembarks, enters a number of amphibian lorries that were carried on board, and attempt to make their way across unknown territory until they find a suitable place near the Equator. After having prepared this as an aerodrome, the other two landing boats can descend and the real exploration begins. The whole process appears a trifle fantastic.

In summarizing it may be stated that the book fails to give the proof that the author intends. On the contrary, it shows the extremely narrow limits between success and complete failure within which we should move in attempting such an enterprise with the technical knowledge available at present. However, the author deserves appreciation for the vast amount of work he has done to show the vast dimensions of such a project.

H. F. ZUMPE.

Development of the Guided Missile

(By K. W. Gatland. 133 pp., 45 photos and diagrams. Iliffe & Sons, Ltd. (for *Flight*), London, 1952. 10s. 6d.)

The choice of the word "development" in the title of this work on guided missiles is a little misleading, for to the prospective technical reader it means the rectification or improvement of engineering techniques and its bearing on new weapon configurations. In this respect the subject is dealt with in only a very broad manner, for the book is more concerned with the evolution of the missile as a weapon and its potential means of achieving interplanetary flight.

This, however, is a very small point of disagreement, for this book provides both informative reading and sows the seeds for controversial argument on the various aspects and means of providing for home defence and long range attack.

The author's views on this subject are both outspoken and acidly critical of the policy adopted in this country at the present time, but the far-reaching effect of accepting that guided missiles are imminent in an operational form should also be borne in mind. It is essential that the design of conventional fighters and bombers be pursued until such time as these can be overlapped by the supply of effective and fully proven guided missiles, even if it means that designs and developments in the closing years exist solely as an insurance, ultimately destined for the scrap heap. There is also the difficult problem of

the design and perfection of field handling equipment, and training the necessary personnel.

The book provides a ready means of absorbing many of the published articles, otherwise missed in the technical press—for the majority of readers to whom this book will appeal find it difficult to keep informed on all the projects which have or are being developed at present. An appendix giving dimensional and performance data on upwards of 90 different missiles is unique and will prove invaluable.

The book is also very up-to-date in its brief review of weapons now being developed and which may possibly come into service use in the near future, but due to our rigid and sometimes stupid secrecy, those mentioned are restricted to American types such as the Terrier, Lark, Nike, and Firebird.

The possibilities of the ram-jet are also briefly reviewed, and suggestions advanced for a possible layout of installed equipment, but in assessing the merits of this type of propulsion, it is a little hard to accept the author's statement that it is difficult to visualize a simpler type of unit. The propulsive duct and its burners are no simpler in essence than the pure rocket combustion chambers and its injectors. Both have expulsion systems which are comparable in their complexity of producing pressure, but the single liquid and reduced quantity makes the ram-jet simpler to engineer.

To offset this, the ram-jet demands complicated fuel ratio valvery for the various burning conditions. The use of the propulsive duct as a structural member to carry flight loads will render it heavy when allowances are made for the reduced material strength due to internal burning temperatures and external aerodynamic heating. The operational ceiling quoted as 100,000 ft. seems a little high.

Cost figures are quoted for the war-time production of the V.1 and V.2, at a rate of 5,000 per year for the latter. The cost of £1 per lb. dry weight is very interesting, for it shows that with the added complicated and expensive ground equipment necessary with fully guided missiles, the figure should be halved to make them economical.

The book concludes with some well-worded and informative chapters on possible methods of achieving interplanetary flight.

It is well printed on good quality paper and for the modest sum of 10s. 6d. is a very worth-while addition for your technical bookshelf.

E. B. Dove.

Automatic and Manual Control

(Edited by A. Tustin. xi + 584 pp. Butterworths Publications, Ltd., London. 50s net.)

This is a complete record of the Conference on Control Systems organized under the chairmanship of Professor Tustin and held during the summer of 1951, at the College of Aeronautics, Cranfield. Acknowledged authorities, from all parts of the world, contributed papers upon all aspects of this rapidly expanding and highly utilitarian branch of engineering, thus making of this work the most up-to-date survey of the position in this field available to the student and research worker.

The papers have been classed into eight sections. (1) *Educational problems*, in which Professor Gordon Brown of M.I.T., describes the type of course which, in his experience, should be followed by students preparing to become that product and builder of this modern age, the control systems engineer. (2) *General Theory*, in which general criteria for stability and for optimizing the response of systems are laid down. (3) *Process Control*, or the study of regulators designed to maintain constant some quantity or property of the product of a machine. (4) *Non-linear Problems*, such as the effects of resilience, backlash, Coulomb friction and the saturation of amplifiers and transformers, on the performance of a servomechanism. On-off systems, which are in many ways more economical than the orthodox linear systems, also receive some discussion. (5) *Systems Working on Intermittent Data and Step-by-Step Servos*, dealing with a type of system which is becoming of increasing importance and which must itself fill in the gaps between the data supplied to it, so as to follow the latter, and at the same time produce a continuous output. (6) *The Human Operator*, a fascinating but highly complex topic whose domain extends into psychology and has been very little explored. (7) *Particular Devices and Applications including Analogues*, in which a method for controlling water turbines used in Sweden and various analogue computing machines are described. (8) *Analysis of the Behaviour of Economic Systems*, in which a number of contributors, including Professor Tustin, point out the parallels between economic and servo behaviour. A final section describes the practical demonstrations which were given in support of many of the papers.

Each set of papers on related topics is followed by a synopsis of the discussion which ensued, this serving to amplify and clarify the chief points made in the papers themselves. The latter are well supplied with figures and references and the printers have successfully solved the many problems associated with the setting up in type of the complex mathematical formulæ which cannot be avoided in theoretical work.

D. F. LAWDEN.

Raumfahrt-forschung

(Edited by H. Gartmann. 199 pp., 54 figs. R. Oldenbourg, Munich, 1952. Price D.M. 16.50.)

This book, with its rather ambitious title, consists mainly of five contributions by different authors, introduced by a short preface by H. Gartmann. These contributions are:—

1. Willy Ley. The history of the idea of space travel.
2. Professor Dr. W. Schaub. The mathematical basis of space flight; the two-body problem and the solvable cases of the three-body problem.
3. R. Engel, Dr. U. T. Bödewadt and K. Hanisch. The satellite station.
4. Professor H. Oberth. Stations in space.
5. Professor Dr. H. von Diringshofen. Medical problems of space travel.

The book ends with some notes about the astronautical societies existing in 1952, and the I.A.F., by H.-H. Kölle, and a bibliography of space travel from 1919.

From the title of the book one would expect that it would present at least a more or less complete description of the main problems connected with space travel, and a critical review of the solutions so far achieved or envisaged by different scientific workers in the field (these are by no means unanimous!). Instead the book deals only with a few topics chosen rather arbitrarily and giving, especially in the last three contributions (Engel *et al.*, Oberth and von Diringshofen), only the very personal views of the writers. This is quite useful in itself but it merely adds to the many publications already available on these subjects and to the confusion in the minds of readers caused by the widely divergent results obtained by the different workers.

The above criticism does not apply to the first two articles. Ley gives a comprehensive critical review of the ideas about space travel as expressed mainly in fiction, going back as far as Plutarch! He relates these ideas to the knowledge of the universe at the time when the respective authors produced their works.

The contribution of Professor Schaub occupies nearly half the book; it deals exhaustively with the problems stated in its title and some of this has already appeared as a series of articles in *Weltraumfahrt*. It is written very clearly and is easy to follow, even to a stranger to the subject, provided he has some elementary knowledge of mathematics. We wonder if it would be possible to persuade Professor Schaub to expand his contribution to a textbook which would give the engineer a simplified method for calculating interplanetary trajectories and their elements and save him from the onerous task of adapting the usual astronomical methods for his purpose.

The third contribution is an abridged version of the work of the authors already published in full.* In common with similar efforts it suffers from the uncertainty of the weight estimates, which stand on no firmer ground than those of Dr. von Braun in his "*Mars-Projekt.*"

Professor Oberth, after a short description of his own idea of a satellite station, deals with some of the usual topics discussed whenever the satellite station is mentioned (telescopes, radar-communication, extremely low temperatures, radiation research, space mirror, and solar power station) and later gives a description of his electrical space ship in which solar radiation is used to generate electrical power via steam boiler, turbine, etc. in order to charge the particles to be repulsed from the reaction motor.

Professor von Diringshofen divides his subject into two main parts: problems on which there is sufficient data and general agreement and problems still open to question. The first part deals with acceleration effects and climate in the cabin of a space ship; the author gives the results of acceleration tests on humans. The second part describes the possible biological effects of the lack of gravitational force, of cosmic radiation and small meteorites. The

*R. Engel, U. T. Bödewadt and K. Hanisch. "Die Aussenstation—ein Zukunftsprojekt?" O.N.E.R.A., Paris, September 1, 1949.

author holds the opinion that the existence of the two latter factors might result in difficulties of a high order.

The book is well printed. The line diagrams and graphs are very clear but the few half-tone illustrations are not up to the general standard of the book.

H. F. ZUMPE.

Our Neighbour Worlds

(By V. A. Firsoff, M.A. Hutchinson's Scientific & Technical Publications. 336 pp. 1952. With 26 illustrations. 25s. net.)

This finely printed book is arranged in 14 chapters, has an Appendix, and may be described as a collection of astronomical facts (and a few fancies), with four chapters on space-flight; thus comprising all that is necessary for an interesting and entertaining work. Unfortunately the style does not make for easy reading and the book has been "padded out" too much, being in too many places a mere collection of the opinions of various "authorities," often at variance with each other.

Nevertheless a great deal of information is included between the covers, and it is equally certain that much of it is of dubious value. The chapters on "space-flight" are, probably, among the best, being packed with the ideas of all the better known writers on the subject, though here again the style might have been made more "readable" and a condensed presentation would be easier to follow. On the whole, however, these chapters are a valuable store-house of information, although it is doubtful whether magnetism will enter into interplanetary flight to the extent visualized by the author.

The symbolical illustrations at the beginning of each chapter may be found annoying to some people, while such chapter titles as "Not Cheshire Cheese" (the title of the chapter on the Moon) and "The Perhaps-Wise Old Globe" (for Mars) do not appear to possess any particular merit.

On page 10 the symbolical illustration facing the chapter, entitled "Before the Opening Door," shows a portion of the Moon's disc. This is described as the north-east quarter but is really the north-west quarter. The illustration entitled "A Lunar Scene" is described as an imaginary landscape in the neighbourhood of the mountainous south pole of the Moon. The characteristic ring mountains and craterpits, rills and a *Mare* are shown, though practical observers know that no *Maria* exist in this south polar region. The lunar structures are described as bulwark plains, ring mountains, craterpits and rills. There is no mention of the numerous craters or craterlets. Craterpits are what the name implies, i.e. pits, and have no upraised rims, as the text states, being mere holes and are among the smallest of lunar features. The term rill is no longer used, its place having been taken by the much more appropriate word cleft. On page 165 Bailly is rightly described as the largest bulwark plain, "holds the palm," but its diameter should be 180 miles and not 170.

A little later on we are told that the ring mountains are saucer-shaped with little, if any, level ground about the middle. Tycho, Copernicus and Theophilus are given as good examples of this mountain formation. The three examples chosen are certainly *not* saucer-shaped and have level ground about

the middle, as do many, perhaps the majority, of the ring mountains. Quite rightly the author does not swallow the Meteoric Theory of the origin of lunar formations to the extent that many others appear to have done in recent years and is much more fair in his comments. He seems to be the first to suggest "a meteor the size of Mare Imbrium crashing into the Moon," although he does consider it difficult to visualize such a meteor without rather fatal consequences. It is very doubtful, however, whether water and gases exist beneath the surface where, "in Stygian darkness, rivers and lakes would form."

Among other points, it is not yet accepted that the density of Mercury is greater than that of the Earth; the statement on page 61 that the "light-power" of instruments used for photography may not be of such moment in the case of the Moon and fixed stars, means nothing. Where minute lunar detail or faint objects require to be photographed it is essential to use large apertures, that is, of considerable "light-power." On page 160 we are informed that 20 "lunar meteors," that is, meteors within a presumed lunar atmosphere, have been observed to date. The fact is that, to date, not a single undoubted "lunar meteor" has yet been recorded; some so-called "lunar meteors" have had no other origin than that in their observer's imagination.

It is difficult to see why lunar eclipses are a more important factor than the diurnal temperature variations in "heat-erosion" of the surface. Eclipses are rare and the solar light and heat are withdrawn for at the most two hours, whereas the lunar night lasts 14 days; to say nothing of the variation between sunrise and noon, fully set out in the text. On page 176 the statement that "within the central part (of the polar regions), the Sun never sets and never rises for six months a year" while "it may, therefore, be advisable for the exploring party to pitch their silvered tents somewhere in the vicinity of a lunar pole, where they might be able to complete their mission free from the rigours of the night frost" should be promptly removed from future editions. It is also far from clear why "the lunar soil is probably very fertile" and the cultivation of "moon-grown tomatoes, the size of pumpkins, enormous bananas and super-melons of delicate flavour" is surely out of place in any book which attempts to inspire confidence.

It is equally difficult to follow the reasoning that Venus is colder and Mars hotter than our own planet; certainly there is, as yet, no supporting evidence. The terminator of Mars, at Gibbous phase, is not "hazy," on the contrary it presents a rather sharp outline, with some fading in illumination. On page 242 the statement that Barnard, in his investigations of Martian detail, might have been handicapped by the poor definition of the large instruments used, is absurd; both the Yerkes and Lick refractors are of the highest optical quality, as is also the Meudon 33 inch, used by Antoniadi, of which the reviewer can speak from practical experience.

Probably, the diameter of Phobos is nearer 15 than 10 miles; it is quite an easy object in a 12-inch telescope at a favourable opposition. It is, however, very doubtful, to say the least, that the atmosphere of Mars extends, "in its outer shell," to 2,000 miles from the surface of the planet, so that Phobos "is conveniently placed just outside it." Dealing with Saturn it is uncertain whether the Crepe ring has a faint extension to the surface of the planet.

Observers of the ringed planet will be interested to know that the looser structure of Saturn's upper atmosphere betrays itself by deformations of the limb, notches and bulges.

The nearest of its satellites to Jupiter is called Amalthea but is usually known as satellite V. Callisto is most unlikely to be "gaseous throughout," the author expresses himself that this interpretation is difficult. It may be mentioned, in passing, that the latest observations at the Pic du Midi Observatory do not confirm the "bright equatorial zone on Io."

The fact is that the author is much less sure of his ground when dealing with astronomical matters than in the realm of space-flight and in the mathematical formulae, given in the Appendix, making this section of particular value. It is needless to remark that the coloured frontispiece, by the accomplished artist L. F. Ball, and showing views of Mars, Jupiter and Saturn, portrays the actual colouring in a considerably more vivid fashion than actually seen in a telescope; but this is usual in such illustrations.

Despite the above-mentioned points, a few of many that might have been cited, the book contains a mass of data and should certainly be on the shelves of everyone interested in Astronomy and Astronautics.

H. Percy Wilkins.

The Sky and its Mysteries

(By E. Agar Beet. 238 pp., 14 plates. G. Bell, London, 1952. 15s.)

In reviewing this book we cannot help but quote from the author's preface: "There are already a very large number of books on general astronomy for the non-specialist, and the only excuse for adding yet another is that I was asked to write it." Certainly a disarming opening, and the resulting work can be fully recommended to any reader wishing for a clear and up-to-date account of a science which, despite its great age, is now in its most revolutionary and exciting period. There are numerous (but not excessive) references for readers wishing to take their studies further, and several mentions of spaceflight in passing. Which reminds us that the time has now come when no book on general astronomy can claim to be up-to-date unless it makes some reference to rockets and astronautics—a test which can easily be applied by a glance through the index!

A. C. Clarke.

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